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## Meteorics and Ballistics

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Early in the fall of last year, the Naval Ordnance Laboratory announced that it had obtained direct atmospheric pressure measures to a height of some 90 kilometers above the earth's surface, more than 50 kilometers higher than previous direct measures. These new results were obtained by instruments carried in German V-2 rockets. Of considerable interest to the astronomer was the announcement that these atmospheric pressures showed remarkably close agreement (to within some 20%) with the values that F. L. Whipple had obtained at Harvard in his work on meteors and the upper atmosphere. One should keep in mind the significance of this meteor study, which has been an integral part of the Harvard Observatory research program for the past 15 years. The long-range object does not primarily embody a study of the upper atmosphere, but an investigation of the cosmological significance of meteors, particularly in the relation to our knowledge of the solar system. Such a cosmological study depends upon a knowledge of both the kinematical and the physical properties of meteors. Fortunately or unfortunately, we can study these properties only by observing the interaction of the meteor with the earth's atmosphere. Our detailed knowledge of this atmosphere, particularly in regard to those properties governing an interaction with a meteor, is far from complete. We find ourselves faced with the problem of studying the motion and physical characteristics of an unknown body moving through an only partly known atmosphere. The result has been a kind of "statistical" study of the interaction between meteor and medium. Fortunately, this statistical study provides sufficient accuracy to give a good, quantitative picture of the "thermodynamic" structure of the atmosphere; *i.e.*, pressure, density, and temperature as a function of height. The term accurate can now be applied with some confidence in view of the above-mentioned confirmation by the V-2 data.

Still, we have only a fraction of the cosmological data that were the original object of the research. While the above-mentioned kinematical studies have provided data on the motions of the meteors, the term "statistical" is used here to imply that the composition and shape of the individual meteor and the physical details of the "process" whereby it interacts with the medium have been "averaged out." Thus what remains is a "mean" meteor that is a composite of the physical and kinematical characteristics of meteors of many different showers. Further,

the "statistical" implies a mixing of the parameters specifying the "process" of interaction (between meteor and medium) with those specifying geometrical and physical properties of the meteor. So, for the still-sought goal of "cosmological" data we must disentangle these parameters. We may now, however, consider the atmosphere as a known quantity—and simply study the motion of the meteor within it. In this side excursion to determine the properties of the atmosphere we have, nevertheless, found the solution of a problem that greatly interests the ballistician and aerodynamistician. The products of the research of these latter scientists have heretofore been comparatively earth-bound. Now, however, the advent of the rocket-propelled body essentially "removes the ceiling." The meteoric set of data on the upper atmosphere dispels for the ballistician and aerodynamistician the prospect of having to venture into unknown conditions with their newly designed products.

Likewise, when we proceed to the process of disentangling the parameters which specify the physical characteristics of the meteor from those describing the details of its interaction with the atmosphere, we find again a number of very interesting sidelights. These sidelights arise in the form of problems which must be resolved and solved *en route* to the general cosmological goal. Let us consider in more detail the question which we have labeled the "process" of interaction between meteor and atmosphere. We shall aim at indicating some of these sidelights which appear, at the time of writing, to be involved, particularly in linking astronomical observation with terrestrial laboratory experiment.

## I. The Type of Interaction Process—A Problem of Description.

The interaction between the meteor and atmosphere we see as one phase of the general problem of the motion of a solid body through a resisting medium. Historically, and of course intuitively, we find two general approaches to this problem. In the first, we consider the medium to be a continuum and apply the methods of hydrodynamics. In the second, we consider the medium to be composed of a number of discrete molecules, each of which collides with the meteor in a reaction largely independent of the other molecules. The first approach lies in the field of the ballistician and aerodynamistician. Heretofore the work of these two classes of persons and that of the astronomer have been quite separated. Now, projectiles and aircraft have greatly increased speeds. They are launched higher and higher into the upper atmosphere. Of necessity the ballistician and aerodynamistician have now become aware of the astronomer and the meteoric research which has until recently provided the only reasonably complete, quantitative data on the structure of the upper atmosphere. The work of the ballistician and aerodynamistician relates to a laboratory science with the features of predesigned, controlled experiment. The upper range of missile velocity

and atmosphere at which the work is conducted now approach the lower boundaries of the astronomical region. Thus the astronomer finds himself showing a renewed interest in the output of his terrestrial comrades.

With regard to the second alternative of description, the "discrete impact" case, the astronomer has again a problem "linked" with his other work. Recently much work has been done on the growth of small dust particles in interstellar space. These dust particles are thought responsible for much of the general interstellar absorption. One sees here a close relation to the problem of collision between air molecule and meteor surface. In the case of both meteor and dust particle, the problem is the collision of a molecule, atom, or ion with a solid surface quite cold with respect to a "temperature" measured by the relative speed of impact. This situation forms quite a contrast to the usual laboratory "accommodation coefficient" determinations, where interest centers on the gaseous conduction of heat from a solid which ordinarily has a much higher temperature than the "kinetic" temperature of the gas molecule.

These two methods of description, hydrodynamic and discrete impact, furnish the extreme range of possible processes of interaction. The astronomer must distinguish between them.

## II. The Observational Data—Sensitivity of the Criterion of Distinction.

In both the processes of interaction of the preceding section two factors occur. First, there arises the transfer of momentum from body to medium. Second, occurs the conversion of part of the translational energy lost by the solid body into energy of heating and vaporizing a layer of material from the body. The first factor, momentum loss, we can measure by observing the deceleration of the meteor—*if* we know the meteor mass. This meteor mass we could measure *if* we knew the relation between the amount of radiation from the meteor and the amount of material vaporized from its surface. Thus we see that even before we start to interpret our observational data we need some sort of interpolation formula, *i.e.*, theory, relating observed luminosity to mass loss.

Now, this meteoric "mass-luminosity" relation introduces a new problem in addition to those discussed in the preceding section. Various writers on the subject have generally agreed that solid-body, continuous radiation from the meteor surface as a whole could not provide the observed luminosity. (The amount of radiation calculated under such an assumption falls short of that observed by about a factor 100.) In addition, meteor spectra show most of the energy concentrated in bright lines—indicative of a gas. The commonly accepted picture of meteor radiation shows then a certain amount of the meteor surface volatilizing and colliding with the atmospheric atoms to produce the observed radi-

ation. One carefully distinguishes the interaction between solid and medium—which results in vaporization of a surface layer of the meteor, from the reaction between the volatilized material and medium—which provides the observed radiation. This latter, radiation, process we do not consider here, besides pointing out that it is an essential part of the interpretation of the observations to gain the meteor mass. This omission arises not from any lack of importance of the process but, on the contrary, from the fact that the radiation process forms by itself a subject for discussion. We are here concerned with a discussion of the problems arising from the occurrences up to the vaporization point.

Thus, we see that the observations provide, to the extent of the uncertainty in this meteor mass-luminosity relation that we overlook, data on the momentum loss of the body—*i.e.*, air resistance—and on the rate of energy transfer to the body for heating and volatilization. These observations must provide for (1) a selection of the process of interaction between meteor and medium and (2) a knowledge of meteor shape and size. To furnish a principle of selection, however, one must establish the consequences in regard to (1) and (2) of a formulation of the interaction in terms of the alternative processes, hydrodynamic or discrete impact, mentioned in section I. To obtain these consequences we must return to consider the processes individually.

### III. The Hydrodynamical Process—A Laboratory Model.

We refer to the process as a laboratory model because, when it is admitted to consideration, the astronomer turns to his colleagues the aerodynamistician and, particularly, the ballistician. The work of the ballistician has been in the hydrodynamical range for a good many years. He has proceeded by now with his theoretical formulation of the process about as far as his experiments range. We must realize that the region in which the ballistician works is thus far characterized by velocities less than about 2 km/sec, and air densities of the same order of magnitude as that at sea level. To date, however, the slowest meteor on the photographic records moved some 10 km/sec and in air at a density less than about 1/1000 that at sea level. Hence the ballistician has been concerned chiefly with the question of resistance force, and little with heating effects. Consequently, when we try to extend the solid ground work, laid by the laboratory ballistician, across the gap to the realm of the meteors, the modifications introduced by heating effects are those for which we are alert.

Naively, we appreciate these heating effect modifications by thinking simply of the case of head-on collision between a small sphere and a large one. For purely elastic collision, no heat transfer, the small sphere's velocity is reversed in direction and retains the same magnitude (relative to a frame of reference traveling with the large sphere). The momentum loss of the large sphere amounts then to twice the

initial momentum of the small sphere. For purely inelastic collision, the momentum loss amounts to just the initial momentum of the small sphere, the loss of kinetic energy appearing as heat. We reach thus the interesting conclusion that the heating effects actually are accompanied by a smaller force acting on the large sphere. So we ask three questions: (a) under what conditions is this hydrodynamical process applicable, (b) what can the ballistician tell about the situation in those conditions nearest his domain, and (c) what are the likely modifications over the conclusions of (b) when we consider directly the meteors?

(a) *A priori* we expect that this hydrodynamical process will be valid when the history of the collision between air molecule and meteor depends greatly upon the other air molecules; *i.e.*, when the change in the kinetic state of the molecule brought about by the collision is communicated to the other molecules while the original molecule is still within "striking distance" of the body. Or we may say this by requiring the free path of the molecule to be less than the meteor dimensions. This constitutes the usual criterion stated in the astronomical literature. If however we inquire into the details of the descriptive methods used in hydrodynamics we find another restriction — the existence of a "boundary layer."

This added requirement had its origin in the famous "Bernoulli Paradox" of classical hydrodynamics. The mathematical formulation of classical hydrodynamics gives no net force on a body that is symmetric about its mid-point and is moving with constant velocity in a viscous-free, incompressible fluid. However, in all such cases arising in practice, a non-zero resistance is measured. Since the viscosity of air is known to be small, and compressibility effects negligible for very small velocities, this conflict between theory and observation provided several hundred years of headaches. It is now realized, however, that the fault lay in the formulation of the equations. Like the general laws of mechanics they were invariant under a reversal of time and velocity. That is, the pressure would be the same, at the same point, on this symmetrical body if it moved forward or backward. Thus it must be acted on by no net force when moving in either direction. This *reversibility* was removed by realizing that the air at the very surface of the body must be at rest relative to it. Hence Prandtl postulated the existence of a very thin layer of fluid, the boundary layer, across which the velocity dropped from the value predicted by the perfect fluid theory to zero. Across the boundary layer the pressure remained constant, however. Since this loss of directed velocity of the fluid is accompanied by conversion into random velocity, both as thermal motion and turbulent motion, the entropy change accompanying this conversion provides the irreversible element to the flow pattern. Since there occurs no change in the pressure distribution between this new and the old picture, it would appear that the force is still the very small friction

force. But here a more subtle mechanism enters, a separation of the flow from the body surface at the rear. This separation results from the dissipation of energy at the surface. That is, the perfect fluid theory requires, fore and aft, a "stagnation" point, where the air is at rest relative to the body. The motion over the rear of the body thus occurs against an adverse pressure gradient on the way to the rear stagnation point. The energy dissipated in the boundary layer suffices to keep the layers of fluid near the body from reaching the rear stagnation point. The flow then breaks away from the body contour and completely destroys the perfect fluid pattern over the rear. There occurs thus no compensating "push" from the rear, and the body encounters an appreciable resistance.

Now this picture applies to incompressible fluids, and to compressible fluids at velocities somewhat below that of sound. We realize that, if the meteor moved in this velocity range, we would be as much interested in the rear contour of the body as the fore. However, meteor velocities are many times greater than sound velocity. (The nondimensional ratio of velocity to velocity of sound is called the Mach number, M.) We call the meteor velocities supersonic, and in this velocity range the physical picture alters. A phenomenon called a shock-wave characterizes supersonic motion. The presence of the shock-wave may be understood by realizing that the velocity of sound is a "relaxation" velocity by which the medium adjusts itself to the presence of a "disturbing element" and spreads word of its presence. If the disturbance arrives so quickly that the medium cannot relax, something happens. That something is simply the creation of a "boundary," the shock-wave separating the region disturbed from that as yet undisturbed. Across this boundary there occurs a jump in pressure, density, and temperature. From the definition we could obviously also call a sound-wave a shock-wave; but the two differ in that the latter has a non-zero change in pressure, etc., across the wave-front, while the sound-wave, in principle, does not. While in reality this shock-wave has a finite thickness, the numerical value is, for shocks in the normal range, usually of the order of one molecular free-path, and so is very small.

The important consequence for us is that the shock's presence alone makes the flow irreversible; *i.e.,* we can hope to calculate a non-zero resistance even without the boundary layer. In fact, the rôle of the boundary layer in producing separation can even be shown to be unnecessary for supersonic flow; for here we can have separation of the flow from the body contour without frictional cause. Does this mean we may neglect the boundary layer? It does not—if we wish to provide any degree of continuity in the understanding of the interaction process. Although the boundary layer was introduced to resolve Bernoulli's paradox, its presence is still desirable to serve as the transi-

tion from the free-stream, where vicosity is negligible, to the surface of the body where the air is brought to rest by viscous interplay with the body. If we wish to apply our macroscopic hydrodynamic analysis, even with shock-wave produced resistance terms, we must retain this small region where the "details" of interaction between fluid and body surface occur. The physical picture, if we are to adopt the hydrodynamic approach, becomes clear. Referring to Figure 1 we see that the flow pattern is divided into four regions:

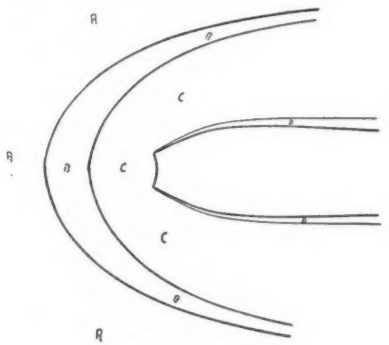


FIGURE 1

A—the region of the undisturbed atmosphere; B—the shock-wave which serves to bring the air from thermodynamic equilibrium under the conditions of A to local thermodynamic equilibrium in C, the region between shock and body; and finally D, the boundary layer where the gas comes to rest in a layer at the surface. The regions A and C are the ones that are treated by the usual, non-viscous hydrodynamical equations. Evidently we cannot hope to apply a hydrodynamical analysis under conditions such that, given the required width of D, we have wandered far from the meteor in units of the meteor dimension. Likewise, a shock-wave will have little meaning if the transition region B is comparable with the region of interest C. In ballistics it is convenient to express the width of D in terms of a parameter called the Reynold's number: $R = v \times \delta x/\nu$. Here the symbols denote the velocity, v, the distance from tip of body to point of interest, $\delta x$, and $\nu$ the kinematic viscosity, or viscosity coefficient divided by air density, $\rho$. For our purpose, however, it is more convenient to realize D cannot be less than the distance a molecule must travel before equipartition sets in between it and the region C. The width of both B and D must be much less than C, which is of the order of the body dimensions. The actual width of B is a microscopically determined quantity—*i.e.*, fixed by an equipartition distance. The region D can be treated hydrodynamically by introducing viscosity terms—up to the final microscopic interaction

with the wall. Then we again discuss an equipartition distance. When the conditions differ only in regard to translational kinetic energy, we expect the equipartition distance to be of the order of one collisional free-path. With temperatures for fast meteors computed on the hydrodynamical model to be of the order of a million degrees,[1] we expect molecular dissociation, ionization, etc., to occur. Here the transition distance should be several orders of magnitude higher. Therefore we are quite sure that the hydrodynamical process cannot occur for very fast meteors, of normal size, high in the atmosphere where the air density is small and the mean path large. But our interest is still held by those meteors moving some 10 km/sec in the regions with density some 1/1000 that at sea level. We remember that the hydrodynamical formulation gives good agreement with ballistic velocities in a region only a factor five removed from this meteor velocity, and at sea level.

(b) Data from the ballistician.

On the basis of part (a) we might expect that the general resistance process could be described by studying the cause of the irreversibility —the shock-wave. For high velocities this conjecture turns out to be quite accurate. We can consider the force on the body to be a "push" backward on the head, compensated to a small degree by a push forward from the base, and a slight friction drag. The force on the head we consider composed of two parts—a pressure "jump" across the shock-wave, and a more gradual rise to the surface of the body. Far more eloquent than a page of description is the following comparison between the theoretically computed force on the head of a cone, and the actual measured retarding force on a body with conical head. We tabulate the comparison at a series of velocities (these velocities are expressed in terms of the Mach number, M). We divide the theoretical force into two parts—the pressure jump across the shock and the pressure rise to the surface. For convenience we express this force in the form of a parameter usually used to describe the resistance; namely, the drag coefficient, $K_d$. We define this as:

$$\text{Force} = -K_d \rho d^2 v^2 \qquad (1)$$

where d = frontal diameter and the other symbols are as defined in the definition of the Reynold's number.

We see the contribution of the shock-wave even more clearly by noting that a graph of $K_d$ *vs.* M exhibits $K_d$ as a decreasing function of M, approaching a constant value. If we consider the actual expression for the pressure ratio on the sides of a shock, divided by $M^2$, we find that it approaches a constant value. (As $M^2 = v^2/a^2 = v^2/(p\gamma/\rho)$, where $a$, $p$, and $\gamma$ are velocity of sound, pressure, and ratio of specific heats, respectively, the relation to equation (1) is obvious.) The non-constant terms fall off as $1/M^2$. The pressure rise from shock to body surface is a slowly varying function, approaching a value near unity in

the high velocity limit. It can be shown that this latter limit is essentially independent of cone angle, so that the shock-term gives essentially the whole description for high velocities. (Table I indicates the trend, even though the velocities are not really high enough to demonstrate limiting values.)

TABLE I

| M | $K_d$ obs. | $K_d$ computed | $K_d$ (shock) | $K_d$ (head) |
|---|---|---|---|---|
| 1.645 | .159 | .266 | .127 | .139 |
| 2.075 | .138 | .185 | .091 | .094 |
| 2.375 | .127 | .149 | .075 | .074 |
| 2.550 | .121 | .133 | .071 | .062 |

(One should note the comparatively low M values given here. The fastest projectiles have been measured[2] at about $M = 4.5$; the slowest meteors correspond to about $M = 25$.)

Thus if we wish to summarize the present status of our knowledge up to the highest velocities yet attained* in the laboratories, we may assert that the theoretical formulation shows the shock-wave term to dominate the qualitative behavior. The experimental results verify this. The meagerness of this theoretical work should, however, be emphasized. Only in one case does a method of calculation exist, that for the pointed head object. Only for one type of this class, the cone, has reasonably sufficient experimental testing been carried out. Because of the nature of the formulation, however, we expect the fundamental physics to be correct, hence the mathematical formulation and prediction. In practice this situation means that we could probably distinguish between a small-angle cone and a sphere, on the basis of deceleration measure on an unknown body at a single velocity somewhat above that which has been covered by experiments to date. We could probably distinguish between any cone and a sphere if a range of velocities were covered. We could not, however, decide easily between a sphere and a cylinder.

(c) When now we proceed to the last section of our comment on the hydrodynamical process, and ask for possible modifications in the extension of these comments to that section of the meteoric range where this process is likely to apply, we realize that we have neglected the problem of heat transfer to the body. That is, the hydrodynamical equations as conventionally formulated do not provide for an abstraction of energy from the air stream. A loss of kinetic energy appears as higher static pressure, etc. Even in the calculations which do exist relative to the effect of the boundary layer on the surface temperature of the body, the authors assume[3] a steady state with temperature of the gas at the body surface equal to the body temperature, and zero temperature gradient at the surface. We recognize, of course, that consideration of the meteor case requires a factor allowing for heat flow to the body. From the simple illustration previously quoted, it would

*Or at least for which the results have been published in accessible form.

seem that the probable effect would be a decrease of resistance if the conditions were such that the hydrodynamical process still held. That is, the extreme case of purely inelastic collision with the molecules all sticking to the surface would obviously vitiate the treatment. If, however, the hydrodynamical treatment did hold, we see that the difference between predicted and observed deceleration results gives a measure of the energy removed from the air stream, *i.e.*, transferred to the body. Since the radiation also provides us with a knowledge of the energy loss (again assuming we know the mass-luminosity conversion, of section II), it would seem that we had an internal check. This would be true only if we knew the body shape; *i.e.*, had a basis on which to predict. Since, however, this shape is one parameter that we are trying to find, the two methods of reaching the energy transfer just suffice to fix the shape. That is, they suffice to fix the shape to a certain degree of ambiguity. This ambiguity becomes apparent when one considers that the resistance predictions depend upon a "resistance" cross-section given by $K_d \times d^2$ and that the energy for heating depends upon both this *and* the surface area of the body. The question which immediately arises is whether the two factors give a unique solution for the two sets of data. One remembers that a meteor is not a "nice" body of revolution but may have irregularities comparable with the body dimension. This question has not yet been much considered, probably because only now are we *beginning* to get data to which we could apply the result. Making no more simplified assumptions than have been used in the meteor-upper-atmosphere work at Harvard, I have made some rough calculations that indicate the meteors may be so irregular in contour as to decrease in frontal area by a factor 1/2 during a time in which the mass loss amounts to only a few percent.

We see in the investigation of this modification from the non-heating, hydrodynamical formulation probably the most immediate direction of advance if we are to bridge the gap from contemporary ballistic knowledge to the meteor problem. We presume that the hydrodynamical formulation will still hold for these slowly moving meteors in the lower atmosphere. That there exists at least a difference in the formulation of the problem in the upper and lower atmosphere is shown by the data on the two or three meteors at these lower levels. In each case, the densities computed *via* the application of the "mean" parameters, which worked well at the higher altitudes, differ from the "standard" atmosphere by about a factor five. (This "standard" atmosphere is the "judicious" resultant of combining the data from many different sources, including the meteors. It has been "fixed" by the N.A.C.A.[4]) The problem of further investigation lies in bridging the gap of heat effects in the hydrodynamical formulation.

We note that we have neglected discussion of the transfer of the mass-motion kinetic energy of the gas into other degrees of freedom

than thermal; *e.g.*, rotation, vibration, and dissociation. This transfer should act on the resistance calculations in a manner similar to that in which energy was transfered to the solid body. That is, the flow pattern (air about the body) becomes altered somewhat by this effect, hence also the computed resistance. For instance, on the basis of some figures on conditions in strong shocks presented by Bethe and Teller,[5] I reach the conclusion that including these effects decreases the computed resistance about 5% for a body with wedge-shaped head of semi-angle 30° at a Mach number 10. This correction must of course be included in the general calculations in order that an "illusory" heat transfer be not obtained.

## IV. The Case of Discrete Impact—the Newtonian Model and the Putty Ball.

(a) Newtonian model: Probably everyone is familiar with the Newtonian model where air molecules are treated as spheres and collide with the body with a coefficient of restitution $e$. In this case the reaction is assumed normal to the surface, and we have:

$$\text{Force} = (\pi/4)\ (1+e)\ d^2 \overline{\sin^3\theta}\ \rho\, v^2. \tag{2}$$

In the equation, $\theta$ denotes the inclination of a segment of the body relative to the direction of motion, and the average is taken over the head. Otherwise, the notation is that of equation (1). This gives for perfectly elastic impact ($e=1$) and a 12°.1 cone: $K_d = .069$. For a sphere is gives $K_d = .785$. Now by comparison with Table I we note that $K_d$ is much less, on this basis, than the theoretical or observed values for the cone. However, a theoretical asymptotic limit for $K_d$ for this cone comes out to be $\pi/4 \times 1.05 \sin^2\theta$ in contrast to the above $\pi/2 \sin^2\theta$. This limit is computed on the basis of the perfect fluid, no-heat-transfer theory. We would expect this perfect fluid value to decrease somewhat from the effects mentioned in the last section and, indeed, on the basis of somewhat sketchy experimental data,[7] this seems to be the case. For the sphere, measures[2] indicate that $K_d$ never exceeds 0.4.

Thus we note that at the higher velocities the case of discrete impact provides definitely higher values for the resistance than the hydrodynamic case. The factor is about two for the simple, no-heat transfer, model. So while on the basis of a *velocity* increase from ballistics to meteorics we should expect a *decrease* in resistance cross-section, on the basis of a *process* change, arising from the decrease of air density, we should expect an *increase* of resistance cross-section. This illustrates well the point so often overlooked in this consideration. There are two effects to be studied, one due to velocity and one to air density, and an understanding of their difference provides a great deal of insight into the physical picture.

From the above we see that both the contour (through $\sin^2\theta$) and the

scale (through $d^2$) enter into the analysis. They enter in a purely geometrical sense, requiring no elaborate mathematical calculation as for the hydrodynamical case, however. Also, the heating of the surface enters directly through $e$, for fixing it fixes the heat transfer. Thus we have the parameters of contour, scale, and heat transfer entering. Actually, however, these factors are not independent, again apart from question of uniqueness, for the heat transfer gives us loss of mass (essentially loss of surface area) and the total mass. This must be compatible with the contour and scale—if we assume the density of the meteor itself to be known.

(b) If now we consider briefly the case of purely inelastic impact, we see that we lose one parameter in the resistance formulation; *i.e.*, that for contour dependence. The air molecule simply "sticks" on the meteor wherever it hits, and the reaction no longer occurs normal to the surface. So we drop the $\sin^2\theta$ term. We have simply equation (2) with $e=0$ and $\sin^2\theta=1$, *i.e.*, effectively we have the meteor transformed into a flat plate perpendicular to the air stream, and the only dimension entering is the cross-sectional area. Here we find the situation already referred to which is akin to the formation of dust particles in interstellar space. In the latter case, the question to be answered is whether the gas atom will "stick" when it hits a dust particle. There exists a considerable difference in size in the two cases. The photographed meteors are usually of the order of a centimeter, while the dust particles are of the order of $10^{-4}$ cm., in diameter. Nonetheless, it is apparent that the physical process of "capture" of the gas atoms or molecules may be quite similar. So once more we encounter an interesting sidelight in the search for the cosmological significance of meteors. Solution of either the meteor problem or that of the cosmic dust must provide data which is of use in the remaining problem. Unfortunately, the cosmic dust problem seems to be a point of considerable dispute among the workers in the interstellar medium; so it is doubtful how much information can thus be obtained. On the other hand we note that Whipple's analysis[6] of the meteor data explicitly assumes that this process of "sticking" is what occurs—*i.e.*, we set $K_d=\pi/4$ in equation (1). As pointed out, however, the analysis requires only momentary "sticking" and also involves averaging over various meteor shapes; so we cannot say that the agreement of the observed atmosphere with the computed establishes the validity of the "sticking" assumption. An error in this assumed value of $K_d$ would simply mean that the average "size" and "shape" of the meteor are somewhat different from those assumed. Or perhaps the mass-luminosity relation we have assumed should be altered.

## V. Summary—What is the Situation in Regard to Further Research.

If we return to the concluding sentence of section II, we recall that

the discussion since then has been a presentation of the terms in which we describe the process of interaction between meteor and medium. By far the greatest attention has been paid in this discussion to the hydrodynamic process, although it is apparent that the majority of the meteors observed do not reach the lower atmospheric levels where such would apply. Nonetheless I feel that it is the study of those meteors which do reach these levels, on the one hand, and attempts by the ballistician to increase the range of his working velocities, on the other, which presents the most likely direction of attack on the problem from the standpoint of unified knowledge. I make this assertion simply because we have a coherent formulation of the interaction processes up to the highest ballistic velocities; the filling in of the gap between these velocities and the lowest meteoric velocities adds to a solid base of knowledge. As we have seen, we seem to have a good idea of the resistance process in the ballistic regime. We look now to the modifications caused by heat transfer processes. That is, we know the method of introducing scale, shape, etc., of the body. We are essentially interested in a one-parameter perturbation of this knowledge, the perturbation caused by introducing heat transfer. If, on the other hand, we begin simply in the higher regions of the atmosphere, we must search completely from a fresh start for all the parameters of interest. Such a fresh start is oftentimes highly valuable to eliminate misconceptions carried along in earlier investigations. In the present case, however, the balance occurs between this fresh viewpoint and the advantage of a "formulation" of the problem from an anchor secured in experiment. It thus seems to the author that the most promising direction of investigation, the one we should "watch" for news of development in this field, is that concerned with bridging the gap between the high-velocity ballistics and the low-velocity meteorics. This mutual application of the other's work has not been present in times past for the ballistician and astronomer, due in no small part to the small circulation of the meager results of high-velocity ballistics. In recent years, improved apparatus has forced into discard the term "meagre." It is hoped that the great concern of postwar science with a wide dissemination of knowledge between the various fields will make "small" equally inappropriate.

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# The Geology of the Moon

By ALLAN O. KELLY

*This paper once more attempts to explain the various features seen on the surface of the moon. After all that has already been written on this subject, it is not very likely that the final word will be contained in a brief discussion such as this. However, the photographs and keys to them furnish interesting material for a detailed study of certain lunar formations, even though the conclusions drawn from them in the paper do not meet with the approval of all readers.* EDITOR.

It was once thought that insanity was caused by looking at the moon too often and too long. Hence the word lunacy. This, of course, was before the days of photography. Now, anyone may study the moon by the use of photographs and avoid the blinding light that the ancients thought affected the mind. One might, however, suspect that most of the present day observations have been made by the direct visual method, judging by the different results obtained, especially as they pertain to the origin of the craters on the moon.

The moon is, indeed, a very interesting subject and more than ever in the mind of the public because of the statements in the Press that we may soon get to view it from a much closer vantage point, due to the development of rocket propulsion.

The study of the physical aspects of the moon is one that has gone on continuously since the invention of the telescope. All of its features, craters, mountains, and so-called seas, have been closely studied. Names have long since been given to all of its prominent features and endless argument has been carried on as to the cause of these features.

In fairness it should be said, that probably nothing is more certainly known than the motions of the moon, and its physical dimensions. The argument, the difference of opinion, arises out of man's desire to know the causes of these physical features.

The moon has a prominent part in nearly every book about astronomy and most of them devote some space to the question of what caused the craters. It has become such a moot question that most, if not all, of the modern astronomy books give all of the arguments, pro and con, and let the reader take his choice. They say in effect,—your guess is as good as ours!

It is the purpose of this article to bring out some new facts about the relationship between these craters and so-called seas, and to show how the geology of the moon is the key to a new concept of the geology of the earth. The following observations were made from a study of a series of photographs (7x9 inches in original) obtained from the Mount Wilson Observatory and more particularly from three photo-

graphs designated by the Observatory as H-8, H-13, and H-17. These pictures will be here-in-after referred to by the above numbers.

These 7 x 9 inch photographs were enlarged to 21 x 27 and hung on the wall so that they could be studied from a distance and so that the finer detail could be better seen. This method of study resulted in the conclusion that every feature on the moon, large or small, is directly or indirectly the result of impact by some cosmic body — meteorite, comet, or planetoid—and that the same thing is true of the earth except that we have had the added effects of erosion and gravitation.

Let us begin with a study of the smaller craters on the moon. There are thousands of them, of all sizes down to about three miles in diameter, the smallest that can be seen on photograph H-8. These small craters are uniformly alike. They resemble the crater made by an explosive shell. Their inner walls are more nearly vertical than the outer, which slope away gradually. Apparently the rock material was thrown out by the force of the explosion but not sufficient heat was generated to melt the floor of the crater. This general condition seems to prevail until we reach craters of about twenty miles in diameter when a small central peak begins to appear. This central peak continues to grow in proportion to the side walls of the crater, until a crater diameter of about sixty miles is reached. From sixty miles upward to seventy-five miles the central peak diminishes until it practically disappears at about seventy-five miles. The walls appear to remain about the same height up to a crater diameter of about 140 miles, the diameter of Clavius.

The probable reason for this correlation between crater diameter and height of central peak is this. As the size of projectile increased, the diameter of the resulting crater increased. Likewise the heat generated was greater so that the magma produced became progressively more fluid. At a diameter of about 20 miles, the heat generated was sufficient to partially melt the floor of the crater around the projectile so that a small mound of very viscous lava was left in the center of the crater. The center of this mound usually fell in, leaving a small crater within a crater. Examples may be seen in photograph H-8 to the right of the center. As the size of crater increased, the heat generated was greater and the lava or magma produced became less viscous. This viscosity decreased until it no longer was able to stand up and harden in that position. Beyond that point it began to slump down a little before it cooled. This trend continues until a point is reached at a diameter of about 75 miles where the lava becomes so fluid that no central peak can remain. Perhaps the best example of the maximum central peak and crater walls is seen in the crater Theophilus (left center of photograph H-17). In this case the viscosity of the lava was just right so that it stood up like whipped cream. It has long been known that similar craters can be made by shooting a projectile into mud of the

right consistency. All of the various types of craters seen on the moon, from those 20 miles in diameter to ones the size of Mare Imbrium, can be produced by changing the fluidity of the mud.

From a diameter of 75 miles up to about 140 miles, little difference is apparent in the shape of craters. Their floors seem to be level, smooth, lava beds, with here and there smaller craters of later origin scarring their surfaces. The names of some of these larger craters or "walled plains" are, Clavius, Schickard, and Schiller. Their diameters are 140, 134, and 110 miles, respectively (See photograph H-13). Their walls are about the same height as other craters of much smaller diameter so that the ratio of wall height to diameter seems to decrease with increasing size. Clavius is usually considered to be the largest crater on the moon by those who believe in the collision theory although it should be plain to anyone who will study the photographs, that the so-called seas are also of impact origin.

Astronomers have named ten of these circular lakes of lava although there are really about fifteen on the visible side of the moon. Some are much older than others and their outlines are not very plain and nearly all are joined closely to others or intersect other circles. The fact that all of the seas on the moon are nearly round is a good argument for impact origin, but there are many more. While the seas on the moon appear to be round when seen on a small scale picture of the full moon, a closer study of any of these seas shows that their edges are quite irregular. The heat produced by impact was so great that the lava flowed like water, welling up and overflowing all of the lower surrounding areas and partially engulfing old craters along its edges. Mare Humorum is a fine example of this condition (See photograph H-13). It shows every indication that it was made by impact. Frozen waves of lava are seen around its edges like ripples from a stone dropped in a pool. Other circular cracks and ridges are seen far out in the surrounding mountains, formed around the same point of impact. Several older and smaller craters around the sides of Mare Humorum have tipped into this once molten sea, so that their inner rims are submerged. What evidence could be plainer? The largest of these craters tipping into Mare Humorum is called Gassendi. It is about 73 miles in diameter and shows a group of three low central peaks. Mare Humorum has a longer diameter of about 200 miles and a shorter one of 180 miles.

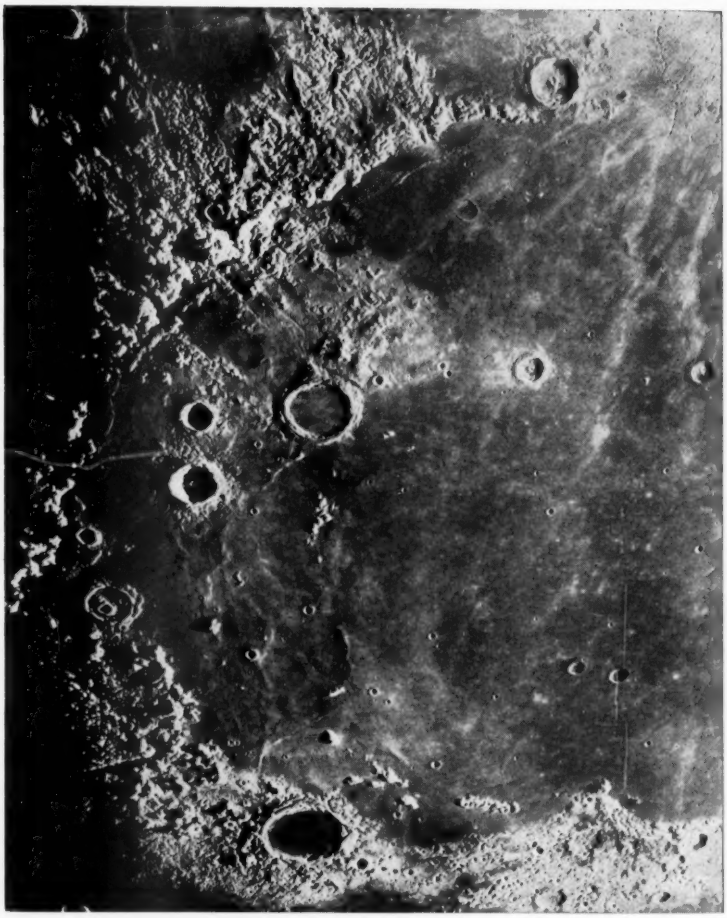
The largest of the so-called seas on the moon is Mare Imbrium. It is roughly 500 by 700 miles and was probably made by a planetoid that came in at an angle, because a high rim of mountains was thrown up on one side and none on the other (See photograph H-8). It is apparently of later origin than most of the other seas because it has thrown out material across the others nearby. There are many signs of grooves and ridges radiating from Mare Imbrium, some of which are nearly 1000 miles from its center. The Apennine mountains forming its upper

left-hand rim are so obviously of impact origin that it seems impossible that anyone could overlook the fact. Their inside edge forms the crater wall and they have been flung out in ridges like the fingers of two hands. A series of shock-waves have cut across all these fingers at right angles, making a screen-like pattern, but somewhat less noticeable than the radiating features. The lower left-hand rim of Mare Imbrium is formed by a ring of mountains known as the Alps. They are about as high as the Apennines, some peaks rising to over 19,000 feet but not so broad across the base. Apparently the greater part of the blast was directed toward the upper left-hand quadrant, judging by the greater mass thrown out and by other features such as the direction taken by lava waves on the surface of Mare Imbrium and by a secondary wave or ridge at the foot of the Apennines which is lacking along the Alps. The right-hand half of the crater of Mare Imbrium has no rim of any consequence because, being away from the direction of blast, the molten magma merely flowed out into the lower areas of old seas and craters along its sides, leaving a less definite rim.

The largest crater within Mare Imbrium is one called Archimedes, located toward the upper left-hand rim (Photograph H-8). It must have been made by a body immediately following the main planetoid which struck while the lava was still viscous because its floor is the same level as that outside its rim. Other meteorites, which struck after the floor of Mare Imbrium had hardened, have left deep pits far below the surrounding surface. This would indicate that craters like Archimedes and Plato (directly below in the rim of Mare Imbrium) were either made while the magna was still hot or else they were old craters whose floors were remelted by the great heat from below. The first possibility seems more likely than the second, especially in the case of Archimedes, which, being directly in the path of the material thrown out, should have been completely filled with debris. However, there are other signs that old craters were completely submerged or nearly so. There are signs of faint rims directly between Archimedes and Plato, and toward the top of the photograph (H-8) there is a horseshoe-shaped crater whose upper rim has been melted by a wave rebounding from the Apennine wall.

Other interesting features are isolated peaks such as Piton which rises more than 19,000 feet above the level of Mare Imbrium. It, and other peaks like it, are probably the remains of old craters, either the central peak which was protected by its surrounding rim, or the more protected side of a crater whose other rim was completely melted.

There are many recent craters on the surface of Mare Imbrium as before mentioned. Aristillus, the largest of these, has a fine central peak. It is about 35 miles in diameter and has a depth of about 15,000 feet. Just below its rim can be seen the faint rim of an older and smaller crater. To the right of Piton about 60 miles may be seen a tiny groove



PHOTOGRAPH H-8
(Made at the Mount Wilson Observatory)

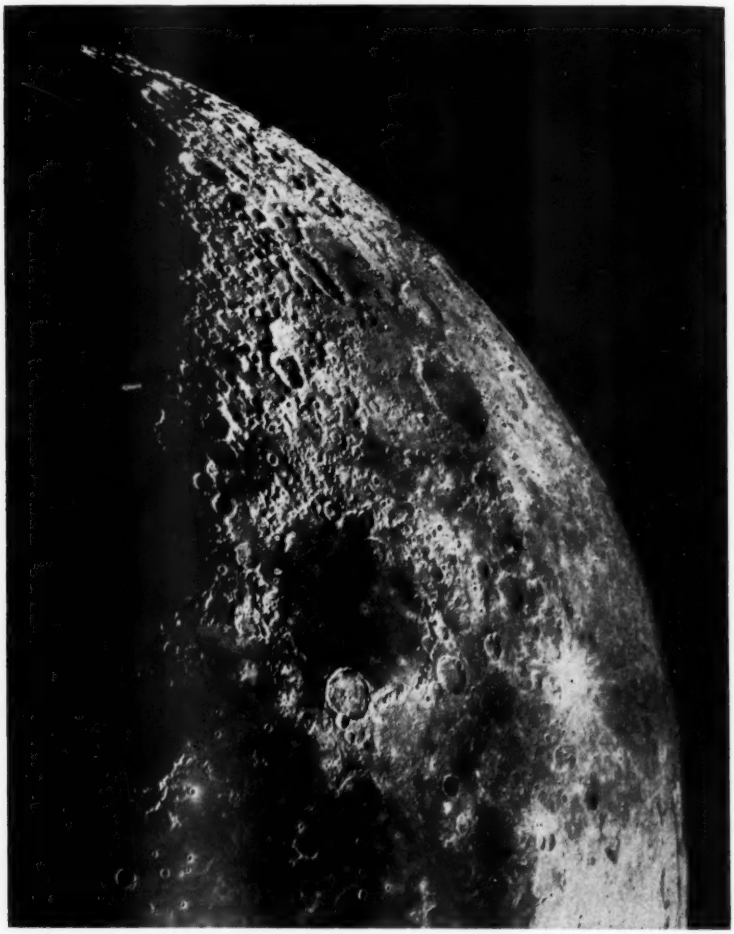
crater. This may have been made by a glancing blow from some meteorite or from a rock thrown out of Aristillus. There are many other interesting details on the surface of Mare Imbrium but the foregoing should be sufficient to show that it could have been made by the impact of a planetoid. Let those, who will, try and explain the above details by any other means!

Still other interesting features on the lunar landscape are the Ray Craters. The largest of these are Tycho, Kepler, and Copernicus. The

TRACING OF PHOTOGRAPH H-8, CALLING ATTENTION TO CROSS HATCHING PATTERN IN ALPS AND APENNINES AND OTHER FEATURES MENTIONED IN TEXT.

light colored rays radiating from these craters extend for hundreds of miles across every other feature on the moon. They are probably the most recent of the craters and the rays are doubtless made of rock flour hurled out of these craters.

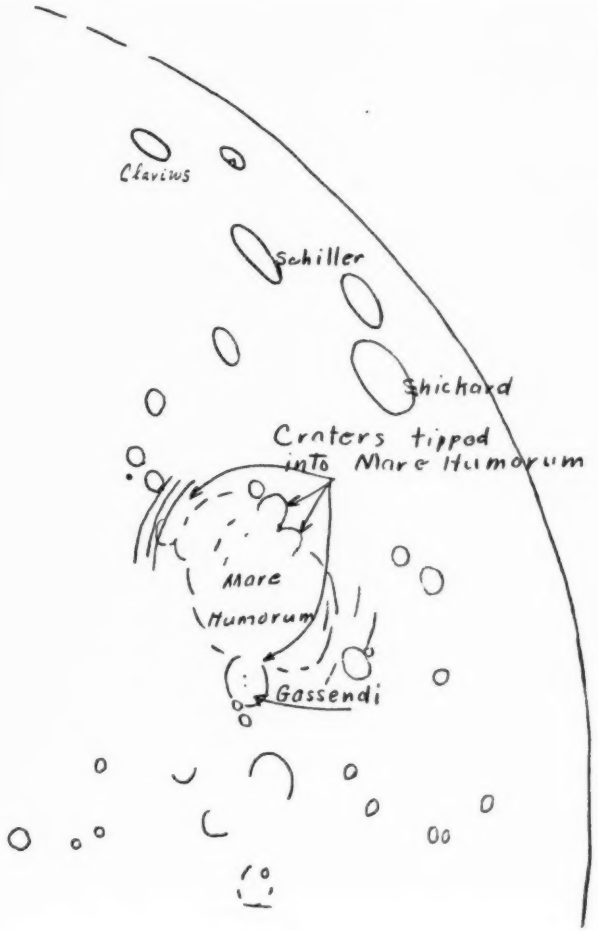
The theory that the craters on the moon are of meteoric origin was advanced many years ago, but only one scientist, so far as the writer knows, has ever advanced the theory that the seas on the moon are of



PHOTOGRAPH H-13
(Made at the Mount Wilson Observatory)

impact origin too.* That man was Nathaniel S. Shaler (1841-1906), professor of geology and paleontology in Harvard University. Shaler thought that these lava seas were caused by meteorites ten to fifteen miles in diameter crashing thru the crust of the moon, and liberating

*Since writing this paper I have learned that Dr. H. H. Nininger in a paper in *Scientific Monthly* for March, 1943, advanced the same or at least a very similar idea.

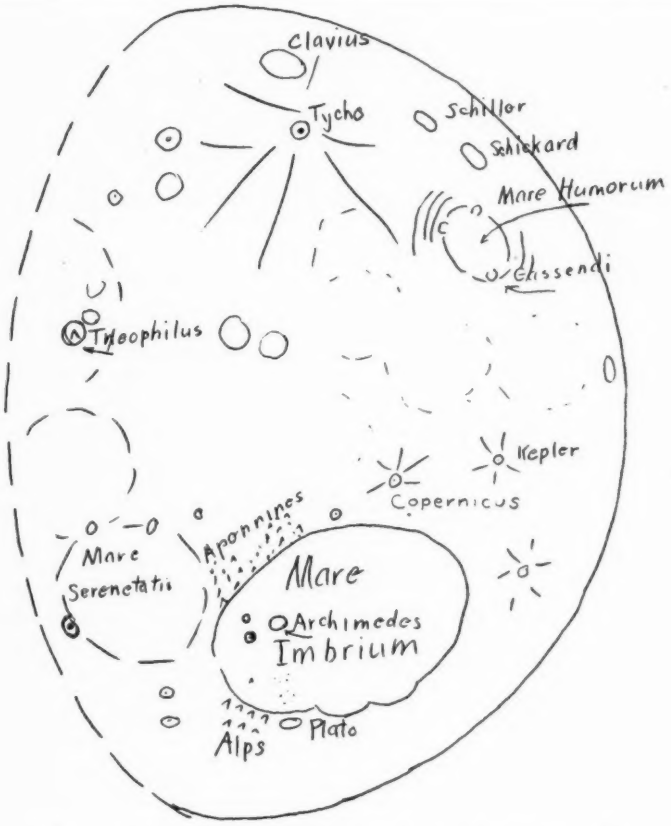



TRACINGS OF PHOTOGRAPHS H-13 SHOWING SOME OF THE FEATURES MENTIONED IN TEXT.

the molten magma, according to Dr. Clyde Fisher, an authority on the moon. The writer has been unable to determine if Shaler carried his theory any further or connected it in any way with terrestial geology. In any event, other scientists did not take the idea seriously, because if they had, it is very difficult to understand how they could have reached any other conclusion. The writer reached this conclusion without knowing of Shaler's statement.

PHOTOGRAPH H-17
(Made at the Mount Wilson Observatory)

Most textbooks and books on popular astronomy, in discussing the craters on the moon, bring out as the chief objection to the theory of impact origin, that no such multitude of meteoritic craters are found on the earth. Only 27 on the earth and the largest of these the Arizona Crater. Why, they ask, has the earth not been struck by even greater numbers of these bodies, considering its greater mass and gravitational power? The answer to this question is simply this. The earth has been struck by thousands upon thousands of these cosmic bodies of all sizes,




TRACING TO IDENTIFY CERTAIN FEATURES IN PHOTOGRAPH H-17.
MOON 19 DAYS OLD.

many of them of such great size that we fail to recognize their craters. If we could reverse our position and view the earth from the moon, we might be able to see the outlines of these craters. They could not be as plainly visible as the lunar ones, however, because we have all of the agents of erosion that are lacking on the moon. Study the globe carefully with these things in mind, and you will see that the mountains and oceans of the earth form a series of intersecting circles of all sizes. Their forms are sometimes very dim but they are there to see and study. The oceans are the beds of most of the large craters and the mountains are their rims. These old crater rims have not only been worn away by the ordinary means of erosion but also by the cataclysmic floods that accompanied these major collisions. These floods must have

removed most of the scars as soon as made and covered over still older scars with deep layers of sedimentary material that later hardened into rock. The shock of such a collision would also disrupt the crust of the earth in adjacent parts, allowing lava to flow out and mountains to be built. The great revolutions noted by geologists as bringing epochs to a close represent these major collisions. Long periods of ordinary erosion accompanied by lesser collisions were interspaced between these major ones but the main source of change in the earth's crust has been collision. The surface of the moon is our best visible proof of this fact.

In 1904, T. C. Chamberlin, one of the great geologists of all time, and F. R. Moulton, a mathematical astronomer, proposed a new account of the earth's origin which they called the "planetesimal hypothesis." They began at the very beginning of things and carried the growth of the earth thru to maturity by the process of planetesimal accretion, but there they stopped. They failed to see the implications of their theory, that collisions would cause change in the earth's surface. They failed to connect the evidence on the moon with that on the earth. They saw no reason for believing in cataclysmic deluges, a theory quite commonly held by early geologists, so they continued with the principles of Sir Charles Lyell.

Sir Charles, it will be remembered, stated his chief premise in the year 1833: "That no causes whatever have changed the earth except those which still do so under the eyes of man." Lyell denied cataclysmic change so forcefully that his premise is still held after 114 years by the vast majority of scientists. Of course, many religious people believe in the Bible story of the flood, a story that is certainly of cataclysmic nature, and one borne out by the legends of many other races of people.

The error that Sir Charles Lyell and his followers have made is this. They have taken the 4000 years of recorded history (leaving out the legends they didn't like) as a fair sample of time. Four thousand years is "but a grain of sand on the shores of time." Because such a cataclysm has not occurred in the last few thousand years is no valid argument that such things are impossible. Lyell made a positive statement that has been taken as truth just because it was conservative.

From this brief account of the geology of the moon it will be seen that great vistas of speculation open before us as we look back down the "corridors of time." We see how, under the collision theory, the earth and moon could have had different orbital speeds, rotational speeds, inclination of axes, eccentricity of orbits, realignment of axes, and many other minor and accompanying changes during past ages. The moon is a mirror of time unchanged by the ravages of erosion.

# A New Discovery in Magnetism*

By PROFESSOR E. N. DA C. ANDRADE, F.R.S.

A fortnight ago Professor P. M. S. Blackett, best known to his brother physicists for his work on cosmic rays, read a paper before Britain's Royal Society which opens up a new prospect in the fundamentals of physical science. It had to do with the magnetism of the earth and of the sun, in which Blackett became interested because of the effect of this magnetism on cosmic rays. Nearly fifty years ago Arthur Schuster, considering the magnetism of the earth and suspecting that the sun also had a magnetic field, asked: "Is every large rotating body a magnet?" Blackett's paper answers this almost forgotten question with an emphatic "yes" and brings forward strong evidence in support of this view.

Let us be clear as to the exact point, the exact novelty of the contention. Consider the fact that the earth acts as a great magnet. It is a well-known law of physics that a moving electric charge behaves like an electric current and creates a magnetic field, so that if the earth were in some way associated with large electric charges in motion its magnetism might possibly be accounted for. There have been many attempts to explain the fact that the earth is a magnet by assuming charges, kept moving in different ways, but they have all been unsuccessful when it comes to calculating the size of the effects which are observed. The size of charges and the kind of motion that would produce the required magnetic field are different from anything that our observations record. At one time it was supposed that the earth's core, which pretty certainly consists of iron, was responsible, but above a certain temperature iron is not magnetic, and the interior of the earth is certainly hotter than this limiting temperature.

Other theories have been tried, which explain the earth's magnetism by supposing that some physical process of a known kind is going on in the earth, but they have all failed when tested by calculation. Blackett's paper is not another attempt of this kind: he does not suggest a new way in which the known laws of physics can be applied to explain the earth's magnetism. He contends that every large rotating body must be a magnet, for some reason that we do not yet understand, and which has nothing to do with the ordinary laws of magnetism and motion as applied, for instance, in the theory of the dynamo. The strength of the magnet is fixed by the spin of the body. This is putting it very roughly—in the physicist's language I should say "the magnetic moment is proportional to the moment of momentum." The "magnetic moment" of a magnet is what measures the field that it will produce at any point, so that for ordinary purposes it is all right to call it the

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strength; the "moment of momentum," often called the "angular momentum," is made up from the mass and the speed with which a body is spinning and measures, roughly speaking, the twist required to set it spinning. Blackett's formula says that the magnetic moment due to the spin can in all cases be got just by multiplying the angular momentum by a certain number.

I suppose that many of you will say at once: "Well, then, why not spin a large body, say a large ball of marble, in the laboratory and see if you get a magnetic effect?" The answer is as simple as the question—the formula shows that to get a magnetic effect large enough to measure you would have to spin any body of reasonable size so fast that it would fly to pieces by the centrifugal force. A successful experiment does not look possible at the moment, but if we learn one day to measure much smaller magnetic forces we may be able to carry it out. Taking an example from a related branch of physics, we know that the earth and the sun attract one another by gravitation, and therefore two lead balls in the laboratory should attract one another but calculation shows that the effect is minute. Minute as it is, however, we can already measure it, so let us hope that soon we shall learn how to measure the other effect.

The evidence on which Blackett supports his law—I don't like to call it a theory at this stage—is provided by three celestial bodies which are all magnetic: the earth, the sun, and a star called 78 Virginis (number 78 in the constellation of the Virgin). You may wonder why only three, when the heavens are full of stars. I, on the other hand, think it pretty wonderful that there are three, and not only one, the earth. You will easily understand that the earth's magnetic field and spin can be measured, but what about the sun? Its magnetic effect at the distance of the earth is far too small to be detected. Its magnetism can only be measured because magnetic force has an effect on atoms which are giving out light, an effect which slightly modifies the frequency of the light, that it slightly changes the appearance of the spectral lines. The effect is very small, but it can be measured with the modern astronomer's great weapon, the spectrograph. There are other things which affect the spectral lines: for instance atoms moving rapidly towards you give light which has a slightly different frequency from that given out by atoms going away from you. This is called the Doppler effect: it enables us to measure the spin of stars, because one side of a spinning globe will be moving towards us while the other is moving away.

These effects on spectral lines are small, complicated and confused by still other effects, so that they need very careful sorting out. It so happens that only one star besides the sun has ever had its magnetic field measured, and that is 78 Virginis, and the measurement was announced only this year by Dr. Babcock, an American. Blackett worked out the spin of the star and found that the ratio of the magnetic

moment to this spin—or moment of momentum—came out to be just the same as it is for the earth and for the sun. The values are very rough, but when you think that the magnetic moment of the star is about 30,000,000,000 times that of the earth, it would be very strange if it was just by chance that the angular momentum also turned out to be about 30,000,000,000 times that of the earth. We must hope that soon a measurement on another star or stars will be possible. A further confirmation of Blackett's law would place it beyond doubt.

Take it that the law is true—and so far nobody has criticized the work adversely—why are physicts excited about it? At present the property of gravity, the attraction which bits of matter exert on one another, stands outside the other forces of nature. Magnetism, electricity, light and other kinds of waves are all interconnected, but gravity is not included in the scheme. Nearly a hundred years ago the great Faraday wrote in his diary: "Gravity. Surely this force must be capable of an experimental relation to electricity, magnetism and other forces, so as to bind it up with them in reciprocal action and equivalent effect." Having previously found, after long effort, a connection between magnetism and light, he tried in vain over many years to find a connection between electricity and gravity. Now Blackett's law connects a purely mechanical quantity with magnetism, and the formula contains the particular number, known as Newton's constant of gravitation, which expresses the strength of gravitational attraction. For the first time magnetism is linked with mere mass properties. For many years great theoretical physicists like Einstein have been trying to find a satisfactory connection between the gravitational field and the electromagnetic field. This work of Blackett's will certainly stimulate the search; for a theory which includes manifestations of gravitational and electromagnetic forces should provide an explanation of his law, an explanation which is at present lacking. When the old laws won't explain experimental observations new ones have to be set up and tested. This new law is a bold generalization, and it smells to me like the kind of generalization that starts a new advance.

# Astronomy and the Modern World

By J. J. NASSAU

**Why study the stars? Why bother with exploring the remotest ends of the universe? What good is there in spending millions to build large telescopes? In this age, when every effort seems to be bent toward seeking the practical, when Europe and the rest of the world need bread, Europe and the rest of the world are planning to re-establish their observatories and build new ones in order that they may share with us the task of searching the unknown in the vast spaces that lie even beyond the stars.**

England is to build a one-hundred inch reflector, to be known as the Sir Isaac Newton telescope. Russia is planning several large instruments, some new and others to replace those destroyed. A large astrophysical observatory is to be established in the Crimea. Sweden is to build a Schmidt-type telescope at Uppsala and France is contemplating the construction of new astronomical equipment. Even in Germany astronomy is reviving. Many European committees are visiting American observatories, seeking new ideas and formulating plans. Europe lacks the Carnegies and the Rockefellers and private foundations. The governments there are supporting astronomy and for what purpose?

Astronomy like other sciences has practical values. It provides the means of measuring time, it helps the navigator and the surveyor. It studies the behavior of the sun in order to explain phenomena on the earth such as changes of weather or changes in radio-wave propagation. The utilization of the radiation of the sun as a source of power is quite practical. Some day the sun's energy will be harnessed. But the sun is a star and to understand its behavior and its life history we must study other stars, just as we study animals to learn more about the particular animal, man.

Within the deep interior of the stars energy is generated, that is light and heat. The atoms of hydrogen are changed to atoms of helium through a series of nuclear reactions to produce the enormous energy necessary to make the stars shine. Our own sun to keep shining, has been consuming four million tons of its material every second for at least two billion years.

Physicists in their laboratories have been engaged in the study of such nuclear reactions and the energy derived from them. The story of uranium and plutonium is familiar to all of us. Astronomy has its share in such activities because in the stars it is possible to study matter under conditions that cannot be duplicated in the laboratories. In the interior of a star the temperature rises to many millions of degrees, the pressure to many millions of atmospheres and matter attains a high degree of compactness as the atoms are stripped of their electrons. Such conditions are unattainable at present in the laboratories.

Astronomy is also helping the chemists. Through the study of the spectrum of the sun the element helium was discovered. Now astronomers are formulating theories regarding the origin of the elements. They are investigating the reasons why some elements are more abundant than others in the universe and the possibility of the existence of elements other than the 96 known ones. Even the "shooting stars," those tiny particles of cosmic dust which enter the earth's atmosphere, have practical value. Through our study of them we have learned that the atmosphere some forty miles above the earth has a temperature of about one hundred degrees centigrade, just the temperature required to boil water at sea level.

The development and improvement of instruments such as the telescope, the spectroscope, the light-sensitive tube and the improvement of photographic materials may be readily credited to the astronomer.

With more fundamental significance astronomy has furnished the means for the formulation of Newton's law of gravitation and Einstein's relativity theory. It influenced the development of many branches of mathematics through the study of celestial mechanics. More recently it has played an important role in the development of statistical methods.

Astronomy has assisted the other sciences and in doing so has become an integral part of them. At present the various sciences cannot be treated as isolated parts. Scientific discovery advances on many fronts and its effectiveness is in direct proportion to its unity of action.

But are the fruits of practical application the only product expected from science? Science offers more than the mere bread of facts and convenient gadgets. Science concerns itself with the human standards of values and develops a deep spiritual understanding over and above abstract thinking. Science has beauty and a strong appeal as do music and other forms of art. Science has profound philosophic implications which have been and are shaping our every day thinking and conduct.

Copernicus' life work brought about not only a revolution in astronomy but a revolution in nearly all branches of human thought. The new knowledge that the earth is not in the center of the universe but revolves about the sun has had more than scientific interest; it has reshaped the lives of men. The geocentric concept placed man in a position of false importance from which it has been difficult to dislodge him since the dogmatic thinking of the period was part and parcel of such a concept.

The struggle to broaden our horizon continues; the earth is but a tiny planet, the sun but a mere star among the billion of stars which form our galaxy. The distances between stars are so great that a beam of light which left a "nearby" star on the day Copernicus was born has not reached us yet. The center of the universe is fading farther and farther from this earth of ours. As our telescopes increase in power more galaxies come into view, many millions of them, and each of them made up of billions of stars.

The vastness of the physical universe naturally makes man feel his great insignificance and yet his ability to comprehend this universe, even to a limited extent, should elevate him to a state of true significance.

Warner & Swasey Observatory, Case School, Cleveland, Ohio.

# Professor P. Guthnick
## 1879-1947

By OTTO STRUVE

Professor P. Guthnick, formerly Director of the Berlin-Babelsberg Observatory, died in Berlin early in September, 1947. He was born at Hitdorf on the Rhine in 1879. He served as Assistant at the Berlin Observatory in 1901, becoming astronomer at Bothkamp in 1903. He was appointed Observator at the old Berlin Observatry on the Encke-Platz in 1906.

Since 1921 he served as Director of the new Observatory at Babelsberg. During the years preceding the first World War he experimented with selenium and other photoelectric photometers, a field in which he was one of the early astronomical pioneers. Among his many photometric investigations the discovery of the periodic variation in the brightness of $\beta$ Cephei ranks among the most important. Guthnick has also carried out a number of spectroscopic investigations and his work on the peculiar phenomena preceding and following the eclipse of Zeta Aurigae stand out because of the great importance of this star in explaining the structure of the atmosphere of the supergiant K-type component.

Guthnick was active over a period of many years in the Council of the Astronomische Gesellschaft and in the years preceding the second World War made a number of futile efforts to exclude politics from this organization and to maintain its scientific independence. He is perhaps best known for his long collaboration with Prager, not only in joint photometric investigations, but also in the Commission of Variable Stars of the A.G. which prior to the second World War was responsible for the work of scrutinizing all variable star discoveries and of attaching names to those that were considered well established. Little is known concerning his activities during the past seven years. After the occupation of Berlin by the Allied Armies he continued work as Professor at the University of Berlin and as member of the German Academy of Sciences.

OCTOBER 29, 1947.

# The Solar Eclipse of November 12, 1947 at the Washburn Observatory

By OLIN J. EGGEN

Perhaps one of the most spectacular things about an eclipse, to the beginning student in astronomy, is the fact that it occurs when predicted. In the case of partial eclipse it is even more striking to see the

preassigned percentage of obscuration faithfully fulfilled. The circumstances of the annular eclipse of November 12, as viewed from Madison, Wisconsin, provided an excellent demonstration of this. Madison was near the northern limit of the partial-eclipse track, the *American Ephemeris* predicting that the eclipse would last from 2:10 to 2:22 Central Standard Time, and that (0.002) of the sun's diameter would be covered by the moon at 2:16. (The parentheses about the value 0.002 are those of the *Ephemeris*.) From the position angles of the two contacts, an indentation of 0.02 inch wide and 0.63 inch long could be anticipated to appear at the very bottom of a 10-inch, projected image of the sun. Twenty-five members of Professor Stebbins' class in elementary astronomy were on hand to view this eclipse which fortunately coincided with their classroom introduction to the phenomenon. The sky was completely overcast some 30 minutes before eclipse time with occasional thinning of the cloud layer. At 2:12 CST the clouds over the sun thinned out and permitted the image to be viewed for one-half to one minute intervals until 2:15 when it completely disappeared. The first glimpse of the eclipse at 2:12 showed evidence of the flattening, and subsequent views showed unmistakably the indentation which was estimated to be about an inch long in the average of estimates made by all present. The projected image actually viewed with the 15-inch telescope was 15 inches in diameter so from the *American Ephemeris* prediction of (0.002) we would expect the flattening to be 0.03 inch in depth and 0.95 inch long. The agreement between the observed and predicted values is perhaps partly occasioned by the proximity of the predicted value to exactly 1 inch, but there was no mistaking the fact that the flattening did occur and that the example afforded by the natural phenomenon for a class-room demonstration was a telling one.

MADISON, WISCONSIN.

## The Planets in January, 1948

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

*Sun.* Southern declination, with consequent low altitude and short days, characterizes the sun in January. However, it is moving northward, so that by the end of the month this southern declination is reduced to 17 degrees. The earth is at perihelion, that is, nearest to the sun, on January 2.

*Moon.* The phases of the moon will occur as follows:

| | | | |
|---|---|---|---|
| Last Quarter | January | 3 | 5 A.M. |
| New Moon | | 11 | 2 A.M. |
| First Quarter | | 19 | 6 A.M. |
| Full Moon | | 26 | 1 A.M. |

The moon is at perigee, that is, nearest to the earth, on January 26.

A grazing occultation of Mars will be visible in the northeast corner of the United States on January 27, shortly after 11 P.M.

*Evening and Morning Stars.* Venus will be visible in the twilight of early evening, while Saturn and Mars will rise later in the evening. Jupiter may be seen in the eastern dawn.

*Mercury.* Only at the end of the month will this planet be as much as 15 degrees east of the sun in the evening twilight, and its low southern position is unfavorable to visibility.

*Venus.* A continued eastward and northward motion relative to the sun will steadily improve the visibility of this most brilliant planet. It will set almost 3 hours after the sun.

*Mars.* Still increasing in brilliance, the red planet will be rising before 9 P.M. at the end of the month. Its close approach and occultation by the moon may be seen on January 27.

*Jupiter.* Early risers may glimpse Jupiter in the southeastern dawn, just before sunrise.

*Saturn.* This planet will be rising before 8 P.M. at the end of the month. With Mars and the first-magnitude star Regulus it forms a short straight line having Regulus in the middle, with Saturn above and Mars below, as seen when they are in the east.

*Uranus.* Uranus will be moving slowly westward, at a position some 3 degrees northwest of $\zeta$ Tauri.

*Neptune.* Neptune will be stationary on January 15 at a point 3 degrees southeast of $\gamma$ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.
November 1, 1947.

## Asteroid Notes

By HUGH S. RICE

CERES is observable in Pisces at least until some time in January. On the last day or two of the year it is about 1° west of $\xi$ Piscium. We have been observing this asteroid and some other bright ones almost nightly. On November 13 the visual magnitude of Ceres was carefully estimated by variable-star observer E. Oravec as 8.0, which is $0^m1$ brighter than our predictions. The planet has been following a large retrograde loop in Cetus and Pisces for many weeks. On December 21 it should be of magnitude 8.5.

IRIS is still in a good situation for observation, a few degrees roughly west of the Pleiades. It is particularly bright at this apparition, and bright for any asteroid. For November 12 our predictions (necessarily based on uncertain elements) were for magnitude 6.9; and for this date Oravec gives 6.7, making it $0^m2$ brighter than forecast. On the basis of these observations we should expect it to be of magnitude 7.7 on December 21, and 8.3 on January 10.

VESTA, near the Gemini-Cancer border, is observable for several months. As usual it is easy to locate with a small glass. Oravec, who had the coöperation

of meteor-observer K. Weitzenhoffer in these observations, gives 7.8 estimated magnitude for November 12; and since then we have found 7.5 for November 20. At this rate Vesta should attain about 6.6 magnitude at its brightest on January 10, near its opposition time.

The subjoined ephemerides (except for extrapolations) are from Dr. Dirk Brouwer of the Yale U. Observatory.

ASTEROID EPHEMERIDES

For 0$^h$ U.T. Equinox 1947 and (for No. 4) 1948

1 CERES

| 1947-48 | α h m | δ ° ′ |
|---|---|---|
| Dec. 11 | 1 45.7 | + 1 16 |
| 16 | 1 44.9 | + 1 39 |
| 21 | 1 44.7 | + 2 5 |
| 26 | 1 45.1 | + 2 34 |
| 31 | 1 46.1 | + 3 5 |
| Jan. 5 | 1 47.7 | + 3 38 |

7 IRIS

| 1947-48 | α h m | δ ° ′ |
|---|---|---|
| Dec. 11 | 2 29.5 | +18 34 |
| 16 | 2 30.1 | +18 6 |
| 21 | 2 31.7 | +17 44 |
| 26 | 2 34.1 | +17 28 |
| 31 | 2 37.4 | +17 17 |
| Jan. 5 | 2 41.5 | +17 11 |
| 10 | 2 46.3 | +17 10 |

4 VESTA

| 1947-48 | α h m | δ ° ′ |
|---|---|---|
| Dec. 11 | 8 4.3 | +20 29 |
| 16 | 8 1.8 | +20 50 |
| 21 | 7 58.6 | +21 13 |
| 26 | 7 54.8 | +21 39 |
| 31 | 7 50.3 | +22 6 |
| Jan. 5 | 7 45.3 | +22 34 |
| 10 | 7 40.0 | +23 2 |

Hayden Planetarium, American Museum of Natural History,
New York, N. Y., November 19, 1947.

## Occultation Predictions for January, 1948

(Taken from the *American Ephemeris*)

| Date 1948 | Star | Mag. | IMMERSION Greenwich C.T. | IMMERSION a | IMMERSION b | IMMERSION Angle E from N | EMERSION Greenwich C.T. | EMERSION a | EMERSION b | EMERSION Angle E from N |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | h m | m | m | ° | h m | m | m | ° |
| OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′ | | | | | | | | | | |
| Jan. 4 | *m* Virg | 5.2 | 11 27.7 | −2.2 | −0.1 | 95 | 12 35.5 | −0.8 | −2.0 | 339 |
| 28 | MARS | −0.7 | 5 5.1 | .. | .. | 195 | 5 22.7 | .. | .. | 224 |
| OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′ | | | | | | | | | | |
| Jan. 4 | *m* Virg | 5.2 | 10 57.9 | −1.1 | −0.6 | 135 | 12 15.8 | −1.6 | −0.7 | 302 |
| 15 | 290 B.Aqar | 6.4 | 22 40.9 | −3.7 | −2.0 | 111 | 23 23.3 | +0.8 | +3.5 | 171 |
| 22 | 192 B.Taur | 6.2 | 6 15.0 | .. | .. | 357 | 6 25.7 | .. | .. | 340 |
| OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′ | | | | | | | | | | |
| Jan. 4 | *m* Virg | 5.2 | 11 10.3 | +0.4 | −3.3 | 183 | 11 58.9 | −3.5 | +1.5 | 258 |
| 16 | $\psi^3$ Aqar | 5.2 | 2 7.0 | −0.9 | −0.3 | 71 | 3 11.5 | −0.1 | +0.6 | 223 |
| 22 | 192 B.Taur | 6.2 | 5 44.6 | −1.6 | +0.4 | 60 | 6 53.4 | −0.8 | −1.3 | 277 |
| OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′ | | | | | | | | | | |
| Jan. 3 | *k* Virg | 5.9 | 15 12.2 | −1.1 | −2.1 | 151 | 16 24.7 | −1.7 | −1.4 | 285 |
| 4 | 575 B.Virg | 6.2 | 15 0.2 | +0.8 | −3.8 | 190 | 15 39.0 | −4.0 | +1.0 | 246 |
| 16 | $\psi^3$ Aqar | 5.2 | 1 54.4 | −0.3 | +1.9 | 15 | 2 54.9 | −1.6 | −1.3 | 271 |
| 18 | $\mu$ Psc | 5.1 | 23 27.1 | −1.7 | +1.5 | 74 | 0 41.4 | −1.0 | +2.4 | 207 |
| 22 | 192 B.Taur | 6.2 | 5 12.6 | −1.6 | +2.5 | 31 | 6 15.0 | −1.9 | −2.1 | 292 |

The quantities in the columns $a$ and $b$ are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under $a$ for the star to be observed; similarly, with the latitude, using $b$; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

# METEORS AND METEORITES

## Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

**Edited by FREDERICK C. LEONARD**

**Department of Astronomy, University of California, Los Angeles 24**

### The Rockwell Hardness of Siderites*

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ABSTRACT

The Rockwell hardness of 22 siderites (nickel-iron meteorites) was determined and found to range from 45*T*-42 to 45*T*-69 and from *B*-60 to *B*-92. Differences were found between the unaltered and the granulated parts of siderites with an alteration zone. Metal near nodules may differ from that farther away. Some experiments were made to determine the effect of heat on the hardness of siderites.

Very little work has been done on the hardness of the metal in meteorites; I find only 2 references in the literature. S. A. Gordon[1] has published the hardness of the Hoba, Grootfontein, Southwest Africa, ataxite, but I have not seen the original paper, and the correlations in the abstract are mutually inconsistent; I judge the most probable value to be Brinell 232. T. Hodge-Smith and A. B. Edwards[2] state that the hardness of the Tawallah Valley, Northern Territory, Australia, ataxite (C.N. = *1357,157*) is Brinell 229 to 255 in different places. In order to fill in this gap in our knowledge of meteorites, I have determined the Rockwell hardness of 22 siderites (nickel-iron meteorites). At first, a Rockwell Superficial Hardness Tester was used.† Most of the determinations were repeated later when a Rockwell Standard Tester had become available. In all cases but 3,

*Read at the 10th Meeting of the Society, San Diego, California, 1947 June 18-19.

†The Superficial Tester does not use the more familiar *B* and *C* scales; instead, it uses an *N* (diamond-brale) and a *T* (Ball-penetrator) scale. Either of these is pressed on the specimen with loads of 15, 30, or 45 kg. The hardness is indicated by a figure such as 45*T*-50; this means that a hardness number of 50 was obtained when a load of 45 kg. was used on the *T* scale.

the 45*T* and *B* scales were used. Correlations have been worked out between these and other scales, such as Brinell, but the correlations are not very exact for certain alloys, including those of iron and nickel; accordingly, I have given the hardness on the scales actually used, but, for convenience, I have included the approximate equivalent on the more familiar Brinell scale (3000-kg. load). In all cases, flat slabs with clean surfaces were used, and, when the width of the lamellae permitted, all tests were made on a single kamacite lamella to avoid interference from taenite. It was assumed that the lamellae did not differ among themselves. This assumption was proved in the cases of Canyon Diablo I, Arizona, and Arispe, Sonora, Mexico.

TABLE 1

| Siderite and Description | Class | Rockwell 45*T* | Rockwell *B* | Brinell |
|---|---|---|---|---|
| Mount Joy, Pennsylvania | Hb | 50 | 77 | 141 |
| Ainsworth, Nebraska | Hb | 62 | 90 | 185 |
| Arispe, Sonora, Mexico | Ogg | 47.5 | 79 | 140 |
| Canyon Diablo I, Arizona | Og-Ogg | 50 | 82 | 148 |
| Gladstone, Queensland, Australia | Ogg | 60.5 | 89 | 178 |
| Gladstone, Queensland, Australia (near FeS nodule) | | 51 | — | 144 |
| Clark Co., Kentucky | Og | 63.5 | 89 | 179 |
| New Leipzig, North Dakota (unaltered) | Og-Ogg | 65 | 89 | 179 |
| New Leipzig, North Dakota (alteration zone) | | 42.5 | — | 123 |
| Xiquipilco [Toluca], Mexico, Mexico | Om | 47 | 91 | 162 |
| Willamette, Oregon (granular type) | Om | 48 | 74 | 136 |
| Willow Creek, Wyoming | Om | 51.5 | 81 | 149 |
| Henbury, Northern Territory, Australia (unaltered) | Om | 55 | 84 | 157 |
| Henbury, Northern Territory, Australia (twisted slug) | | 64 | — | 192 |
| Canyon Diablo II, Arizona[7] | Om | 56 | 83 | 159 |
| San Angelo, Texas | Om | 56 | 83 | 159 |
| Odessa, Texas | Om-Og | 57 | 83.5 | 162 |
| Odessa, Texas (near FeS nodule) | | 54 | — | 153 |
| Bristol, Tennessee | Of | 44 | 60 | 117 |
| Huizopa, Chihuahua, Mexico | Of | 51 | 79 | 144 |
| Bethany (Mukerop), Great Namaqualand, Southwest Africa (near FeS nodule) | Of | 56 | 80.5 | 159 |
| | | 54.5 | — | 155 |
| Chupaderos, Chihuahua, Mexico (plessite) | Of | 54.5 | 76* | 155 |
| Chapaderos, Chihuahua, Mexico (kamacite) | | 59 | | 170 |
| Chupaderos, Chihuahua, Mexico (edge of alteration zone) | | 60 | — | 176 |
| Chupaderos, Chihuahua, Mexico (within alteration zone) | | 61 | 86 | 174 |
| Saint Genevieve Co., Missouri | Of | 63.5 | 90 | 187 |
| Bear Creek, Colorado | Of | 28.5† | 42‡ | 330 |
| Tazewell, Tennessee | Off | 69 | 87 | 158 |
| Monahans, Texas ("Eotaxite")[2] | $D_1$ | 66.5 | 92 | 200 |
| Hoba, Grootfontein, Southwest Africa[1] | $D_1$ | — | — | 232 |
| Tawallah Valley, Northern Territory, Australia ("Eotaxite")[2] | $D_1$ | — | — | 242 |
| Synthetic Superfine Octahedrite (Ni 27.69%) | — | — | 78 | 140 |

Notes to Table 1

*$G$ scale. †45$N$ scale. ‡$C$ scale.

It will be noted that, in the case of the Chupaderos, Chihuahua, Mexico, iron, the alteration zone is harder than the unaltered metal. Silliman has reported that the Shingle Springs, California, ataxite ($D_1$Sh) was hardened to a depth of 4 to 5 mm. from the surface[3]; my tests, however, indicate that the alteration zone of New Leipzig, North Dakota (undescribed), is softer than the unaltered metal. The Soper, Oklahoma, ataxite ($D_2$S) also is said to be hardened near the sur-

face.[4] Artificial heating of another siderite also caused some hardening; therefore the softening observed in New Leipzig is not typical. It will be observed further that, in 3 cases, the hardness was tested near sulfide nodules, and that, in each case, a perceptible decrease in hardness was detected. Light-colored, diffuse halos may be seen around the sulfide nodules of some ataxites. This fact appears to be due to the increased fineness of the structure. Care was taken to make these tests far enough away from the nodule to eliminate edge effects. The synthetic superfine octahedrite was made by myself and has very fine, tho rather perfect, Widmanstätten figures. This specimen will be described more fully in a later paper.

Chiefly because of the discrepancy in the hardness of the alteration zones, discussed previously, some tests were made on the effect of heating strips of Canyon Diablo, Arizona, iron. The results are summarized in Table 2. It is clear from the table that even long heating below the transition temperature does not greatly affect the hardness. Heating above the transition point, for even a very short time, results in hardening, especially if the iron is quenched in water. Cold work (hammering) results in about the same amount of hardening. Fusion causes considerable softening, unless carbon is added. The effect of working on the hardness of iron may be seen also from a comparison between the 2 specimens of Henbury, Northern Territory, Australia, listed in Table 1; one was a large specimen showing no signs of the twisting and heating that occurred at the time of impact, while the other was a small specimen with highly confused and distorted figures; this showed a substantial increase in hardness. It is seen from Table 2 that, altho short heating above the transition point causes hardening, prolonged heating, followed by slow cooling, results in a much smaller hardening effect. This fact explains, perhaps, why irons like Huizopa, Chihuahua, Mexico, and Canyon Diablo II, Arizona,[7] which resemble the alteration zones of other irons, nevertheless show no greater hardness than do other irons of similar type and composition. It is true that Canyon Diablo II is slightly harder than Canyon Diablo I, but Nininger[7] is of the opinion that Canyon Diablo II is a separate fall that accompanied Canyon Diablo I from space.

TABLE 2

| Treatment of Specimen | Hardness, 45*T* |
|---|---|
| Untreated specimen of Canyon Diablo iron | 48 |
| Heated to 425° C. for 15 hours | 47 |
| Heated to 670° C. for 13.5 hours | 50 |
| Heated to 980° C. for 1 hour | 56 |
| Heated to 980° C. for 3 hours and slowly cooled during 2 hours | 52 |
| Heated to 980° C. for 1 minute and quenched | 60 |
| Heated to 980° C. for 1 hour and quenched | 61 |
| Hammered until no increase in hardness resulted | 59 |
| Same specimen heated to 990° C. for 1 minute and quenched | 62 |
| Same specimen reheated to 990° C. and cooled slowly | 50 |
| Same specimen reheated to 1040° C. and cooled slowly | 47 |
| Fused and cooled somewhat slowly | 45.5 |
| Fused on charcoal and cooled slowly | 57 |
| Xiquipilco iron, untreated | 47 |
| Xiquipilco iron partly fused and cooled somewhat slowly[5] | 48 |
| Henbury iron, untreated | 55 |
| Henbury iron fused and cooled somewhat slowly[6] | 45.5 |

REFERENCES

[1] S. A. Gordon, *Proc. Acad. Nat. Sci. Philadelphia*, **83**, 251, 1931.
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[4] W. F. Foshag, *Am. Min.*, **24**, 59-61, 1939.
[5] J. D. Buddhue, *C. S. R. M.*, **1**, No. 3, 25-7; *P. A.*, **45**, 275-7, 1937.
[6] J. D. Buddhue, *C. S. R. M.*, **2**, 126-8; *P. A.*, **47**, 387-9, 1939.
[7] H. H. Nininger, *C. S. R. M.*, **2**, 193-7; *P. A.*, **48**, 328-32, 1940.

## A Possible Meteorite Crater in the Hawaiian Islands

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I should like to draw the attention of meteoriticists and other interested persons to the existence of a possible meteorite crater in the Hawaiian Islands. According to K. P. Emory,[1] there is a place called *Ka-imu-hoku* ("The Star Oven"), on the Island of Lanai. It is so called because it is "a place where a meteor fell." Not far away is a beach called *Ka-hoku-nui* ("The Large Star"), because "a meteor once fell nearby." Elsewhere he says that *Ka-imu-hoku* is "a pit in the sand where a meteor fell."[2] According to a map, these places are located on the north coast of the Island, in the Mahana District, near the border of the Maunalei District. The coördinates of the locality are approximately long. W. 156° 53′5 and lat. N. 20° 54′, according to the Coast and Geodetic Survey of 1914. The latitude is N. 20° 55′, according to the Government Survey of 1878. A pit in a sandy beach, unless very large, would be a rather impermanent feature, but investigation of the area might result in the recovery of fragments of the meteorite (on the assumption that there was one), or perhaps fragments of fused sand, or both. At any rate, the fact that it is "a pit in the sand" would seem to distinguish the crater from the features of volcanic origin that are so common in the Hawaiian Islands. It is to be hoped that this area will be carefully investigated. Some connection with the Honolulu, Oahu, stone of 1825 (C.N. = 1578,213; cl. = Cwa) is possible.

REFERENCES

[1] Kenneth P. Emory, *Bull. 12, Bernice P. Bishop Mus.*, Honolulu, Hawaii, pp. 27, 20, 1924.
[2] *Ibid.*, p. 31.

## A General Definition of the Coördinate Number of a Meteoritic Fall

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ABSTRACT

A general definition of the coördinate number (C.N.) of a meteoritic fall is given, and, in view of that definition, certain recommendations concerning the use of C.N.'s are made; also, simple notations for indicating negativity in C.N.'s are proposed.

The coördinate number (C.N.) of a meteoritic fall has been defined as a 7-digit number, of which the first 4 digits equal the longitude of the actual place of fall, and the last 3, the latitude, each coördinate being expressed in units of a

tenth of a degree; if the longitude is east (negative), the first 4 digits are italicized, while, if the latitude is south (negative), the last 3 are italicized.[1] This definition may be generalized thus: The C.N. of a meteoritic fall is a $(2n-1)$-digit number,[2] of which the first $n$ digits equal the longitude of the actual place of fall, and the last $(n-1)$ digits, the latitude, each coördinate being expressed in units of $10^{3-n}$ degree; . . . . . A coördinate mesh may be defined as an area on the Earth's surface within which all points have the same C.N. Evidently the smaller the mesh the more closely is the place of fall delimited.

In the accompanying table are contained, for (1) 7-, 9-, 11-, and 13-digit

TABLE 1

APPROXIMATE DIMENSIONS AND AREAS OF COÖRDINATE MESHES

| (1) C.N. | (2) Ang. Units | (3) Dim. of Mesh (Mi.)* | (4) Area of Mesh (Mi.$^2$)* |
|---|---|---|---|
| 7-digit | $0^\circ.1 = 6' = 360''$ | $6.9\cos\phi \times 6.9$ | $47.61\cos\phi$ |
| 9-digit | $0^\circ.01 = 0'.6 = 36''$ | $0.69\cos\phi \times 0.69$ | $47.61\cos\phi \times 10^{-2}$ |
| 11-digit | $0^\circ.001 = 0'.06 = 3''.6$ | $0.069\cos\phi \times 0.069$ | $47.61\cos\phi \times 10^{-4}$ |
| 13-digit | $0^\circ.0001 = 0'.006 = 0''.36$ | $0.0069\cos\phi \times 0.0069$ | $47.61\cos\phi \times 10^{-6}$ |

C.N.'s, (2) their angular units, and (3) the approximate east-west and north-south dimensions in miles and (4) the approximate area in square miles, of their corresponding meshes. For even a 9-digit C.N., the mesh is obviously small enough to be subjectable to field search. It is recommended, then, that, henceforth, the largest C.N. compoundable from the known geographical coördinates of a fall be assigned to it.[3] A 7-digit number should always be employed, however, unless the location is known with sufficient precision to warrant the assignment of a larger number; in other words, numbers of more than 7 digits should never be provisional—they should always be definitive. 7-digit numbers will probably continue to be most serviceable generally as reference numbers, but, in future catalogs, 7-, 9-, 11-digit, and, in very exceptional cases, even larger numbers may appear, the size of the number, in any instance, depending upon the accuracy with which the coördinates of the place of fall have been determined.

In accordance with the definition of the C.N., the negativity (in the case of an eastern longitude and/or a southern latitude) has been indicated by italicizing (or underlining) the digits representing the negative coördinate or coördinates. This practice may well be superseded by the use of: (1) a (+) sign—or, better, *no* sign at all—before the number, if both coördinates are positive; (2) a ($\pm$) sign, if the longitude is west (+) and the latitude is south (—); (3) a ($\mp$) sign, if the longitude is east (—) and the latitude is north (+); and (4) a (—) sign, if both coördinates are negative, as illustrated in the following examples (for 7-digit numbers):

| Name of Fall | C.N.[4] |
|---|---|
| Canyon Diablo, Coconino Co., Arizona, U.S.A. | 1110,350 = 1110,350 |
| Otumpa, Tucuman, Gran Chaco Gualamba, Argentina | 0615,*275* = ± 0615,275 |

*$\phi$ = the "middle latitude" of the mesh.

| Name of Fall | C.N.[4] |
|---|---|
| Ensisheim, Alsace, France | $0074{,}479 = \mp 0074{,}479$ |
| Hoba, nr. Grootfontein, Southwest Africa | $0179{,}196 = -0179{,}196$ |

References and Notes

[1] *V.* "A Catalog of Provisional Coördinate Numbers for the Meteoritic Falls of the World," *Univ. of New Mexico Publ. in Meteoritics,* No. 1, "Introduction," pp. v-xi, and the "Principal References" cited therein, pp. vii-viii, 1946.

[2] Where $n$ is a positive integer $\geqslant 3$.

[3] *E.g.,* if the coördinates are known to $0'.6 = 36''$ (or to $0'.5$), a 9-digit C.N. can be reliably assigned. It is therefore urged that the coördinates of every fall be evaluated to the closest $0'.5$ at least.

[4] If the first, or both the first and the second digits of a C.N. are 0, they may be omitted, but if the first 3 digits are 0, the third one, for reasons of clarity, should be retained.

1947 November 1

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### Specific Classes of Five Sideritic Falls of the Western States

On looking over the "Catalog of the Meteoritic Falls of the 11 Western States," by Frederick C. Leonard and Dorothy H. Alley, in *C. M. S.,* **4**, 58-65; *P. A.,* **55**, 381-8, 1947, I find that I can supply information on a few of the falls that are marked only as siderites (Si).

Mount Elden, Arizona, is a coarse octahedrite (Og).

Wiley, Colorado, is a nickel-rich ataxite ($D_3$).

Las Vegas, Nevada, is a coarse octahedrite (Og).

Drum Mountains, Utah, is a medium octahedrite (Om).

Horse Creek, Colorado, is anomalous, consisting of kamacite and schreibersite, the latter copiously precipitated on planes that are almost, but not quite, octahedral—giving the appearance, at a glance, of a highly perfect, finest octahedrite (Off). The planes cannot be octahedral, however, because the phosphide, being tetragonal, has a different space lattice from that of iron. Pictures and some discussion of this remarkable iron are included in my book, "The Metallography of Meteoric Iron" (*U.S. Nat. Mus. Bull. 184*), vii + 206 pp., Washington, 1944.

Stuart H. Perry

Adrian, Michigan, 1947 September 9

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### The Institute of Meteoritics of the University of New Mexico

Attention was first called to the Institute of Meteoritics of the University of New Mexico in a note that appeared in *C. S. R. M.,* **3**, 250; *P. A.,* **54**, 154, 1946. The following excerpt is taken from *The University of New Mexico Bulletin, 56th Catalog Issue, 1947-48,* pp. 27-8:

"The Institute of Meteoritics of the University of New Mexico, apparently the first institute in the world devoted primarily to meteoritical research, has the following objectives: to promote the recognition and recovery of meteorites, not only by systematic surveys with meteorite detectors but also by stimulating the general public to watch for and to report these bodies; to carry on intensive scientific study of meteorites and of terrestrial materials metamorphosed by meteoritic impact; not only to advance such related pure sciences as meteorics [*i.e.,* "the science of meteors," or meteoric astronomy] but also to apply the

results of meteoritical research in such practical fields as those of high-altitude ballistics, ore-detection, and the metallurgy of stainless steels.

"The Institute is ideally located for field work in meteoritics, since the University of New Mexico is situated almost in the center of that subregion of the United States in which the climate is most favorable for the long-continued existence of fallen meteorites in recognizable form; in which the conditions of terrane and rainfall are most favorable for the instrumental detection of buried meteorites; and in which, as a matter of fact, most of the meteorites and all of the meteorite craters thus far found in the United States have been located.

"In addition to conducting research in meteoritics and coöperating with such military agencies as Air Technical Service Command and the Optical Trajectory Section at White Sands Proving Ground, the staff of the Institute is testing and installing instrumental equipment for use in teaching observational astronomy, and is collaborating with the Department of Mathematics and Astronomy in the development of new courses in astronomy and meteoritics. Furthermore, the Institute sponsors a new series of meteoritical monographs, the *University of New Mexico Publications in Meteoritics.*"

The Institute is under the direction of Dr. Lincoln La Paz, Professor and Head of the Department of Mathematics & Astronomy of the University of New Mexico and an Ex-President and Councilor of the Meteoritical Society.

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*President of the Society:* Arthur S. King, Mount Wilson Observatory, Pasadena 4, California

*Secretary of the Society:* Oscar E. Monnig, 1010 Morningside Drive, Fort Worth 3, Texas

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# VARIABLE STARS

## Variable Star Notes from the American Association of Variable Star Observers

**By LEON CAMPBELL, Recorder**

*Finding List of Eclipsing Variables:* No. 22 of the Princeton University Observatory publications contains a very helpful, indeed almost necessary, finding list of eclipsing variables for those professionals or amateurs who contemplate observing any of these variables. The list has been prepared by Dr. Newton L. Pierce, following the pattern set by Dr. R. S. Dugan in the original finding list from Princeton.

Data intended for the observer rather than the computer are given for 546 variables. On the left-hand pages of the catalog are given such important data as period, spectrum, magnitude at maximum, ranges of principal and secondary minima, when both are present, and duration of eclipse. Another column indicates which type of observations are desired.

On the right-hand pages are given voluminous facts as to identification, information about comparison stars, light elements, references to orbital solutions, and lists of observations already secured. Attention is called to the need for observations of the times of minima—even though complete light curves are not obtained—thus supplying data for studying changes in period. Continuity in such

observations of times of minima is especially desirable. Observations of such phenomena are needed at least once or twice a year, on those stars which have shown variations in period. Great precision in estimates of brightness is not required, if one observes on the descending branch, through the bottom and well up on the rising branch.

While the nature of the observations is such that the professional astronomer, with his elaborate photometric devices, will be mainly involved in the work, there are many valuable data which the amateur, suitably equipped, can secure. Detailed hints for observers, visual and photographic, as well as photoelectric, are given. The finding list is strongly recommended for those observers who can play a part in this important program. There is plenty yet to be learned about eclipsing variables, once the observational data are secured.

*AE Aquarii, 2035o1:* The SS Cygni-type variable, AE Aquarii, has been an object of considerable interest for some time, not only because of its spectral peculiarities, but more recently because of its rapid light variations. In a communication received early in October, Dr. Harold L. Alden of the Leander-McCormick Observatory, called attention to the rapid variations of the star and the extremely short time spent at maximum light. He reported that for the three months preceding September 27, the magnitude of the variable fluctuated irregularly between 11.0 and 11.4. On that date, however, it was observed at magnitude 10.5, but had decreased to magnitude 11.2 within three hours. On October 4 it was observed at 11.1; then brightened to magnitude 10.5 within an hour, but dropped to 11.2 within the next two hours.

The variable has been on the AAVSO observing list for some months, but was not observed frequently enough—especially during a single evening—to detect these sudden changes. It is therefore particularly important for those observers who are suitably equipped, that the star be observed on each clear night, and if found to be brighter than magnitude 11.0, it should be observed again that same night. Times should be recorded at least to the nearest five minutes. A "b"-type chart of the region on the basis of Herbig's sequences is being prepared by the AAVSO Chart Committee for distribution to observers.

Mr. A. Wachmann discovered the variability of the star in 1931, and stated that the spectral type was Md, and he assumed that the star was of the long-period type. Zinner, in 1938, found that the star resembled U Geminorum, (or SS Cygni), with a period of 371 days. The U Geminorum-type feature was later confirmed spectroscopically by A. N. Vyssotsky. Dr. A. H. Joy stated that spectrograms obtained at Mount Wilson between September 11 and October 22, 1943, showed the characteristic feature of SS Cygni stars at minimum light, with emission lines of hydrogen, helium, and ionized calcium about 20A in width. Considerable change in structure of the absorption lines also took place from day to day. Joy concluded that the source of the absorption lines is one component of a rapid binary system whose period is not greater than two days. The observed radial velocity range is more than 250 km/sec. AE Aquarii appears to be a variable of more than ordinary interest, and should be studied in the greatest possible detail. A chart may be had for the asking by addressing the AAVSO Recorder at Harvard Observatory.

*Special Variables: U Geminorum,* 074922, was at maximum—wide type—about October 19, following the preceding wide type maximum by 145 days. It is probable that a narrow type maximum occurred in between.

*S Apodis*, 145971, according to reports recently received from South Africa, was still well below maximum brightness, magnitude 14.0 on September 16. The variable decreased suddenly to minimum in January of this year.

*RY Sagittarii*, 191033, which also faded away to minimum a year ago, still remains faint, around the 13th magnitude late in September.

Maximum 359 of *SS Cygni* followed number 358 by 87 days, while 360 followed 359 by only 48 days, and the interval between 360 and 361, the latest observed maximum, was only 37 days.

PREDICTED DATES OF MAXIMUM, 1948

| Design. | Name | Date of Max. m d | Mean Max. Mag. | Design. | Name | Date of Max. m d | Mean Max. Mag. |
|---|---|---|---|---|---|---|---|
| 0010*32* | S Scl | 12 29 | 6.8 | 134440a | R CVn | 7 13 | 7.7 |
| 021143a | W And | 11 7 | 7.5 | 140959 | R Cen | 8 21 | 5.9 |
| 021403 | o Cet | 9 27 | 3.7 | 143227 | R Boo | { 4 28<br>{ 12 8 | 7.3 |
| 022813 | U Cet | 7 2 | 7.5 | | | | |
| 023133 | R Tri | 4 28 | 6.3 | 151731 | S CrB | 8 6 | 7.5 |
| 043263 | R Ret | 8 22 | 7.7 | 151822 | RS Lib | 7 9 | 7.7 |
| 050953 | R Aur | 4 16 | 7.8 | 152849 | R Nor | { 6 1<br>{ 11 3 | 7.2 |
| 051533 | T Col | { 4 13<br>{ 11 24 | 7.6 | 153654 | T Nor | 7 13 | 7.4 |
| 054920a | U Ori | 2 6 | 6.6 | 154615 | R Ser | 7 12 | 6.8 |
| 055686 | R Oct | 4 21 | 7.9 | 154639 | V CrB | 5 14 | 7.4 |
| 065208 | X Mon | { 4 5<br>{ 9 7 | 7.6 | 162112 | V Oph | { 2 18<br>{ 12 14 | 7.5 |
| 065355 | R Lyn | 4 16 | 7.9 | 162119 | U Her | 8 17 | 7.6 |
| 070122a | R Gem | 3 5 | 7.1 | 163266 | R Dra | 6 23 | 7.6 |
| 072708 | S CMi | 11 24 | 7.5 | 164715 | S Her | 8 6 | 7.6 |
| 081112 | R Cnc | 5 7 | 6.8 | 164844 | RS Sco | 10 20 | 6.8 |
| 082405 | RT Hya | { 2 3<br>{ 10 12 | 7.6 | 165030a | RR Sco | { 1 21<br>{ 10 27 | 6.0 |
| 084803 | S Hya | 7 15 | 7.9 | 170215 | R Oph | 8 18 | 7.6 |
| 085008 | T Hya | { 3 11<br>{ 12 25 | 7.7 | 182133 | RV Sgr | 10 17 | 7.8 |
| | | | | 183308 | X Oph | 9 10 | 6.9 |
| 092962 | R Car | 7 13 | 4.6 | 190108 | R Aql | 5 5 | 6.3 |
| 093934 | R LMi | 10 19 | 7.2 | 191019 | R Sgr | { 2 23<br>{ 11 18 | 7.2 |
| 094211 | R Leo | 4 13 | 5.9 | | | | |
| 100661 | S Car | { 5 26<br>{ 10 22 | 5.7 | 193449 | R Cyg | 2 28 | 7.3 |
| | | | | 194048 | RT Cyg | { 3 11<br>{ 9 17 | 7.4 |
| 103769 | R UMa | 3 18 | 7.6 | | | | |
| 114441 | X Cen | 10 29 | 7.8 | 194632 | Chi Cyg | 7 23 | 5.3 |
| 121418 | R Crv | 2 28 | 7.6 | 194659 | S Pav | 7 27 | 7.3 |
| 122001 | SS Vir | 11 10 | 6.9 | 194929 | RR Sgr | 7 11 | 6.6 |
| 123160 | T UMa | { 1 26<br>{ 10 9 | 7.9 | 195142 | RU Sgr | 7 27 | 7.2 |
| | | | | 201139 | RT Sgr | { 2 11<br>{ 12 13 | 7.9 |
| 123307 | R Vir | { 1 14<br>{ 6 7<br>{ 10 30 | 6.9 | 204405 | T Aqr | { 4 2<br>{ 10 21 | 7.9 |
| 123961 | S UMa | { 5 8<br>{ 12 20 | 7.9 | 210868 | T Cep | 4 8 | 5.8 |
| | | | | 221948 | S Gru | 1 29 | 7.8 |
| 132422 | R Hya | 5 28 | 4.6 | 230110 | R Peg | 1 26 | 7.9 |
| 132706 | S Vir | 3 21 | 7.1 | 230759 | V Cas | { 2 24<br>{ 10 9 | 7.9 |
| 133633 | T Cen | { 1 23<br>{ 4 23<br>{ 7 23<br>{ 10 22 | 6.1 | 233815 | R Aqr | 7 19 | 7.3 |
| | | | | 235150 | R Phe | 7 19 | 7.8 |
| | | | | 235350 | R Cas | 11 18 | 6.5 |

*Maxima of Bright Long-Period Variables, 1948:* Predicted dates of maxima for the brighter stars on the AAVSO observing list of 400 long-period variables are listed above. The magnitude column gives the *mean* magnitude of the variable as derived from observations made over many years. The actual observed magnitude at any individual maximum may differ appreciably from that listed in the table, and the star will, of course, be near maximum brightness for some time before and after the dates as given, dependent on the type of maximum, whether narrow or broad.

*Observations received during October:* A total of 4669 observations were contributed during October by 61 observers, as listed herewith:

| Observer | No. Var. | No. Ests. | Observer | No. Var. | No. Ests. |
|---|---|---|---|---|---|
| Addis | 2 | 2 | de Kock | 112 | 461 |
| Ahnert, F. | 3 | 48 | Koons | 59 | 94 |
| Ahnert, P. | 34 | 228 | Lee | 12 | 27 |
| Albrecht | 9 | 9 | LeVaux | 6 | 31 |
| Ball | 16 | 35 | Matthews | 26 | 98 |
| Bicknell | 9 | 22 | Miller | 27 | 30 |
| Bogard | 43 | 130 | Nadeau | 106 | 153 |
| Boone | 5 | 5 | Park | 3 | 17 |
| Buckstaff | 16 | 61 | Parks | 33 | 33 |
| Campbell | 3 | 7 | Pearcy | 73 | 98 |
| Caraioryis | 6 | 12 | Peltier | 182 | 313 |
| Cilley | 20 | 50 | Penhallow | 5 | 8 |
| Cragg | 23 | 24 | Plybon | 4 | 18 |
| Dafter | 5 | 28 | Renner | 109 | 109 |
| Daley | 12 | 19 | Rosebrugh | 14 | 215 |
| Darnell | 4 | 22 | Salzman | 3 | 12 |
| Elias | 97 | 161 | Schoenke | 3 | 3 |
| Escalante | 45 | 52 | Sherman | 38 | 51 |
| Ewen | 3 | 3 | Slemaker | 23 | 35 |
| Fernald | 314 | 1085 | Smith, J. R. | 24 | 24 |
| Garneau | 27 | 32 | Snow | 4 | 6 |
| Greenley | 36 | 102 | Sturtzen | 3 | 3 |
| Gross | 2 | 2 | Swaelen | 5 | 19 |
| Halbach | 12 | 18 | Tarbell | 9 | 30 |
| Harris | 16 | 16 | Thomas | 50 | 102 |
| Hartmann | 144 | 162 | Upjohn | 18 | 31 |
| Hiett | 7 | 22 | Webb | 21 | 21 |
| Inman | 1 | 1 | Welker | 22 | 34 |
| Johns | 3 | 11 | Wells | 7 | 9 |
| Kelly | 14 | 16 | — | | — |
| Kirchhoff | 6 | 114 | 61 | totals | 4669 |
| Kitley | 48 | 85 | | | |

November 17, 1947.

## Comet Notes

By G. VAN BIESBROECK

On October 18 a short ephemeris of Periodic Comet Schwassmann-Wachmann 2 was received by wire at the Yerkes Observatory from H. Q. Rasmusen (Kalundborg, Denmark). This comet comes to perihelion next summer but it is already well situated in Cetus. Plates taken the next day showed the object as

a faint round nebulosity of magnitude 16½ almost exactly in the position predicted by the Danish computer. Originally discovered in 1929, this second comet found by the two observers at Bergedorf (Germany) describes an elliptic orbit in a period of 6½ years. This is the third apparition since 1929. Not until next year, however, will the object come in reach of moderate-sized instruments.

Periodic Comet Schwassmann-Wachmann 1, often mentioned in these notes on account of its surprising change in brightness, was recorded here on October 21 as a tiny round nebulosity of magnitude 18, exactly in the position predicted by P. Herget. As a result of an exhaustive study of the motion of this object he was able to give a reliable prediction for this and three more coming oppositions. The present location is favorable.

| | α | δ | |
|---|---|---|---|
| | h m | ° ′ | |
| 1947 Dec. 1 | 8 12.4 | +25 8 | |
| 11 | 10.0 | 16 | |
| 21 | 6.7 | 25 | (1950.0) |
| 31 | 8 2.7 | 35 | |
| 1948 Jan. 10 | 7 58.2 | 44 | |
| 20 | 53.4 | 52 | |
| 30 | 7 48.8 | 25 58 | |

This comet bears watching continuously on account of the unexpected outbursts of brightness which at irregular intervals have characterized its previous apparitions. For instance in January, 1946, it rose from 18th to 9th magnitude in a short interval, remained bright for a few days then lost in light almost as rapidly.

While the long list of comets under observation has thus been augmented by two more arrivals, several of the earlier ones are getting too faint for further study. The status of these objects is given in the following list for the middle of November. They are given in order of right ascension.

1. Comet Wirtanen (1947 *h*) has faded more rapidly than expected and is now too faint in the evening sky.

2. Comet Jones (1946 *h*) was estimated as of 16th magnitude on November 3. It may be followed for another month before it is lost in the early part of the night. Discovered August 6, 1946, this comet has now been observed for 15 months.

3. Periodic Comet Whipple (1947 *g*) will soon be lost in the evening. It is very faint and difficult to locate on the dense background of the Milky Way.

4. Comet Bester (1946 *k*) has nearly the same appearance as comet Jones at present, being also of 16th magnitude on November 3. Moving slowly in the constellation of Cygnus it will be followed apparently until the end of the year. Visibility has now lasted more than 12 months.

5. Periodic Comet Reinmuth 2 (1947 *j*) may still be observed for some time although the brightness has dropped to 16th magnitude. It moves slowly in the constellation of Pisces.

6. Periodic Comet Oterma 3 (1942 VII). It will be remembered that this object was followed through aphelion in the fall of 1946. When last recorded here, October 23, it was reduced to a tiny nebulosity of 18th magnitude. It is still in reach for some time in the constellation of Cetus.

7. Comet Bester (1947 *k*) is now visible only in the southern hemisphere. It was last seen here on October 23 as a fairly large coma of 9th magnitude, moving rapidly southward. L. E. Cunningham has computed a more accurate orbit fixing the time of perihelion as 1948 February 16. It will be lost in the vicinity of the sun at that time but will emerge shortly afterwards in the morning sky. By the end of February it reaches maximum brightness and should then be fairly conspicuous to the naked eye. The ephemeris will be given in due time.

8. Periodic Comet Schwassmann-Wachmann 2 (see above).

9. Comet Rondanina-Bester (1947 *b*). This object is now too faint even for large telescopes. From a discussion of the available observations, L. E. Cunningham concludes that the orbit shows a marked deviation from the parabola. However the period comes out more than 3000 years.

10. Periodic Comet Faye (1947 *f*), moving slowly east of Betelgeuse, is somewhat fainter than predicted. On October 23 when the comet was near maximum brightness the magnitude was estimated here as 14.5; it showed a well-defined nucleus and a tail about 4′ long in the direction 285°. With large telescopes this comet may be followed beyond the end of the year but it is now beginning to fade. New elements by L. E. Cunningham indicate 1947 September 28.4 as the time of perihelion.

11. Periodic Comet Schwassmann-Wachmann 1. (See above.)

12. Periodic Comet Encke (1947 *i*) has followed its predicted course both in position and brightness. By now it is moving rapidly toward the sun and will be visible only a few more days at low altitude before the dawn. When last seen here, November 11, the brightness was estimated around magnitude 7 but haze made the result uncertain. Maximum brightness of 6th magnitude is expected on November 26, date of perihelion passage, but by that time the comet rises only one hour before the sun. In December it will remain invisible in the vicinity of the sun and lose very rapidly in brightness. Spectroscopic studies by P. Swings at the McDonald Observatory have given new information about the physical constitution of the comet. The results await a full discussion of the observational material gathered at the end of October.

Williams Bay, Wisconsin, November 13, 1947.

## General Notes

**The Rittenhouse Astronomical Society** of Philadelphia held its monthly meeting on November 14, 1947, in Randal Morgan Physics Laboratory, University of Pennsylvania. The speaker was Dr. Herbert R. Morgan, of the United States Naval Observatory, whose topic was "The Work at the United States Naval Observatory."

**Dr. H. van Gent,** an observer in the Leiden Observatory at Johannesburg for many years, died in Amsterdam on March 29, 1947, at the age of 47. He was a careful and persistent observer and, as a result of his diligence, he had accumulated approximately 10,000 plates mostly of parts of the Southern Milky Way, taken for the purpose of searching for variable stars. He had returned to Leiden in June, 1946, for a prolonged study of the important material he had secured.

Dr. van Gent's death brings to six the number of prominent astronomers in the Netherlands lost in recent years. Four young astronomers who had gone out from Leiden died in the years 1944-46 as a consequence of the Japanese occupation of the Netherlands East Indies, and Dr. Wolljer, a long-time valued member of the Leiden Observatory staff died in 1946.

### Solar Noise

A discussion on recent solar activity, at the Royal Astronomical Society on October 10, included among the subjects observations of bursts of solar radiation recorded on radio wave lengths around 5 metres. Although significant results have already been obtained, the relation of solar "noise" to specific solar phenomena is still very obscure. However, it does appear that sunspots, more than any other known solar feature, mark the general place of origin of the bursts, as well as (in some cases at least) of a general increased level of the solar noise.

Solar flares are intrinsically related to sunspots and offer valuable time-coincidence data for comparison. Many of the bursts of solar noise were closely synchronous with the more intense solar flares. But other peaks in solar noise have occurred when no flare was observable.

(*British Astronomical Association Circular* 288.)

### The 200-inch Palomar Mirror

From information received from the Office of Public Relations of the California Institute of Technology we learn that the mirror was moved from the optical shop in Pasadena to the Observatory on Mount Palomar on November 18 and 19. Some interesting facts pertinent to this large project which is without precedent, as furnished by the authority mentioned above, follow:

1. The 200-inch mirror, complete with its mounting mechanism and cell and wooden packing case weighs approximately 40 tons. It was placed horizontally on a 16-wheel trailer, the combined weight of which is approximately 20 tons, bringing the total weight of equipment, the mirror, and its case, to 60 tons. On mountain grades there will be a truck in both front and rear of the trailer.

2. In some instances it has been necessary to shore up culverts along the route to carry this weight and it was also necessary in some instances to lay additional planking across bridges. In all, there are five culverts and three bridges that required this work.

3. The mirror was accompanied by a highway patrol escort which had jurisdiction over the moving, and pilot cars were stationed in front and to the rear of the trucks and trailer.

4. Two I-beams were welded to the trailer bed, and the mirror, in its mounting cell, rested on these, anchored at three points, two of them stationary and the other moveable. Sponge rubber was used at certain points within the mounting cell for cushioning purposes and the tires on the trailer provided all other cushioning deemed necessary.

5. The case which covered the mirror was built of 2 x 12 timbers and was 20 feet square. The top was insulated with aluminum foil to delay temperature changes within the casing.

6. Over main highways the average speed was between 10 and 15 miles per hour. Through towns and over more narrow highways and streets the average was between 3 and 5 miles an hour. The total distance of the route followed was approximately 160 miles.

7. At certain points along the route it was necessary to establish road blocks. This was true particularly on narrow mountain roads and some of the streets and highways over which the mirror was taken.

8. The approximate value of the mirror is $600,000.

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### Leiden Observatory Expedition to Kenya

On August 30, 1947, two astronomers from the Leiden Observatory, Dr. van Herk and Lt. Com. van Zadelhoff, and their families left Amsterdam on an astronomical expedition to Kenya, East Africa. The principal purpose of the expedition, which will last about three years, is to determine the fundamental declinations of all stars contained in the FK III Catalogue between +50° and —50° declination. These determinations will be made by measuring azimuths of stars from a station situated on the equator between Nairobi and Lake Victoria at an altitude of 2900 meters. The same method was used in 1931 and 1932 when Dr. Hins and Dr. van Herk carried out a similar expedition in the same region. Some important changes have since been made in the azimuth instrument. Now observations can be made with it only at an altitude of 9 degrees. This plan was devised because of the troublesome systematic errors in declination, when determined by the meridian circle, due to flexure in the instrument. Such errors are completely avoided by this method since only azimuth measures are made, all at the same height above the horizon. The instrument, therefore, always maintains the same position with respect to the force of gravity. Being situated on the equator, if the observations could be made when the star is on the horizon, it is clear that the azimuth would directly measure the polar distance. Practically, of course, this cannot be done, but the advantages of such procedure will largely remain when working at an altitude of 9°.

In addition to the azimuth instrument the expedition is equipped also with a zenith telescope and other instruments for measuring the intensity of the zodiacal light and also the general background light of the Galaxy photo-electrically.

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## Book Reviews

**Atoms, Rockets, and the Moon,** by Dinsmore Alter. (Griffith Observatory, Los Angeles 27, California. 75 cents postpaid.)

The above is the title of a pamphlet of 44 pages recently received. At first thought the three items mentioned have scarcely any recognizable connection. However, when one recalls that atomic energy has recently startled the world and that consequently it is thought of as having a bearing on any undertaking, such as sending a missile, probably a rocket, to the moon, in which a hitherto unavailable amount of energy is required, one sees that there is a an underlying conection. The writer says, "It appears improbable that its [lunar travel] solution will be linked directly with atomic power. However, the linkage in the minds

of men is so close that the inclusion of the two subjects in this one study seems to be logical."

The author uses the first half of this pamphlet for a detailed and very clear exposition of the research leading up to the release of atomic energy. The last four sections are devoted to more speculative matters. The chapters are entitled, Peacetime uses of atomic power, To the Moon?, Living on the Moon, and Space travel fantasy. Though speculative the presentation is far from fantastic. Although practically all the details of such unusual adventures are still in the pre-experimental stage, the problems involved are here set forth so clearly as to make them seem not only almost real but also fascinating. The reader of this pamphlet is sure to be started upon thinking along new lines. C.H.G.

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**Atlas der Sternbilder,** by Oswald Thomas. (Published by Das Bergland press, Salzburg, Germany.)

This is the latest of a large number of star atlases which are available, having been published in 1945, with the permission, it is stated, of the American military government. This one has several features which are commendable. The format is such as to make it easily used and kept on the shelf with other books. After a preface and some eight pages of explanations intended to make the atlas more easily understood, there follow 91 pages of the charts themselves. These are arranged with stars as white dots placed on the outlines of the classical constellation figures, all upon a background of very dark blue, simulating the night sky. On the page facing the chart in each case is a black and white representation of the same region from which one may read the names of the constellations and the Greek letter designations of the more prominent stars. There is a pair of pages like this for each of the twelve months, for each of 32 of the constellations, and for the south polar region.

Following the charts are 17 pages of descriptions of 88 regions of the sky indicating the various objects of special interest in each. Next there are 25 pages giving in tabular form the coordinates, magnitude, spectrum, and distance of the brighter stars and other objects in each of the 88 regions. The volume is concluded with various indexes which facilitate the finding of any particular region.

Throughout the volume are quotations from well-known German writers pertinent to the study of the stars and its influence upon the student.

It should be added that the book is entirely in German, and hence a knowledge of this language is a prerequisite to the successful use of it. This condition being met, the volume will contribute much of pleasure and interesting information. C.H.G.

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**Atlas Stellarum Variabilium, Series IX,** compiled by J. Stein, S. J., director of the Vatican Observatory, Specola Vaticana, 1941.

The valuable work begun by the late Father Hagen and published under the title of *Atlas Stellarum Variabilium* has been extended by Father Stein, the present director of the Vatican Observatory. His work appears as *Atlas Stellarum Variabilium Series IX.*

The earlier numbers of the Series, I to VIII, were published from 1899 to 1934, and the new Series IX is a welcome addition to this valuable set of charts,

especially prepared for the use of variable star observers. The *Atlas* is accompanied by two numbers of the Vatican Observatory publications, *Ricerche Astronomiche*. The first one, Volume I, Number 3, contains a discussion of the charts by Father Stein and Father Junkes. They give a short history of the *Atlas* and the early work done by Father Hagen, and also a complete description of the determination of the comparison star magnitudes. The other number, 4, gives an index of all the variables contained in the entire series (I-IX).

Series IX contains 43 charts on which 45 variables are marked; 29 of which had been selected by Father Hagen for future charts. Most of the variables are of the long-period type, but the list also includes 9 RV Tauri-type, one nova, and several irregular variables. Series IX charts are for use with slightly larger telescopes than were required for the earlier series, for the minimum magnitudes of the variables range from 12 to 16.

The *Atlas* comprises a portfolio of charts and a companion volume which lists the coordinates and photovisual magnitudes of the comparison stars for each variable. The epoch of 1950 was chosen for convenience of present-day observers.

The charts themselves are very beautifully reproduced from photographs made at the new Vatican Observatory, in Castel Gandolfo. Because the charts are made for use at the telescope, they are inverted (north at the bottom, east at the right, etc.). The variable is located at or near the center. Each chart is at a scale of 40 seconds per millimeter, and covers one degree on either side of the center. A reticle with lines 10 minutes of arc apart is superimposed on the star field.

The magnitudes of the comparison stars are given in the photovisual system. They are based on the North Polar Sequence, reduced to the International Scale. The photographs for the magnitude determinations were taken with the Zeiss Quadruplet of 198 centimeters focal length, and with an aperture of 40 centimeters. Eastman Spectrographic Plates I D were used with a yellow filter, GG II. The plates were measured with a thermoelectric microphotometer, and great care was taken to apply all the necessary corrections.

Users will be glad to know that the description of the current series is written in German rather than in the Latin of earlier numbers.

MARGARET W. MAYALL.

Harvard College Observatory.

# POPULAR ASTRONOMY

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